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Short Descriptions Proceedings

Advanced Solutions for Charging of Electric Vehicles

85kHz Band Wireless Charging System for EV or Electric Bus
Akihisa Matsushita, Fumiaki Takeuchi, Shuichi Obayashi, Masaaki Ishida Toshiba, J; Tatsuro Abe, Toshiba Infrastructure Systems & Solutions Corporation, J
We have developed a 44kW wireless charging system for electric buses, which achieves a reduction in radiated electromagnetic emissions by devising structure alignment. The receive output power of 44 kW or more was confirmed by test verification. And system efficiency exceeds 85%. Moreover we have conducted verification operation tests using electric buses running on public roads. The tests have verified that these wireless charging systems offer enhanced convenience and achieve the targeted power transmission efficiency.

Advanced Vehicle Charging Solutions Using SiC and GaN Power Devices
Bernd Eckardt, Moritz Wild, Christopher Joffe, Stefan Zeltner, Stefan Endres, Fraunhofer Institute IISB, D; Martin März, FAU Erlangen-Nuremberg, D
Very compact and highly efficient charging solutions for plug in hybrid and full electric vehicles are mandatory for the break trough of electric mobility. There fore designs for uni- and bidirectional chargers using SiC and GaN devices are presented. In the very challenging field of inductive charging, a small, lightweight solution is shown and the benefits of SiC MOSFETs compared to Si devices are evaluated.

System Architectures for Multiple Ports, Bidirectional and Buffered Charging Unit for EV's
Alfred Rufer, EPFL, CH
Bidirectional buffered units for Multi-port charging of EV's are presented, allowing to charge with high power even if the line current capability is limited. The systems are also dedicated to operate as reactive power compensators, or to provide grid system services as V2G operation or other power smoothing functions.

Materials for Packaging and Thermal Management

Development of High Temperature Silicone Gels
Makoto Ohara, Shin-Etsu Silicones Europe, D
Market requirements to packaging material (silicone gel)
What happens to silicone gel when it's exposed high temperature?
How to overcome these failure modes?
Introduction of the latest high temperature gels and future target

Silicone Gels for Continuous Operation up to 200C in Power Modules
Thomas Seldrum, Francois Vanderhaeghen, The Dow Chemical Company, BE; Hiroji Enami, The Dow Chemical Company, J
A silicone gel with high temperature resistance (up to 215°C for more than 2000 hours) has been developed. The mechanical softness and high elongation at break, together with the electrical performances have been preserved via formulation engineering and use of additives that can prevent the oxidative degradation mechanisms.

High Temperature Encapsulation for Smart Power Devices
Karl-Friedrich Becker, M. Obst, J. Bauer, T. Braun, Fraunhofer-Institute IZM, D; T. Thomas, M. Schneider-Ramelow, K.-D. Lang, Technical University Berlin, D
Research is presented, that provides a detailed description of the high temperature suitability of encapsulants for power electronics encapsulation ? additionally an extended test methodology is

described to facilitate future material evaluation for HT or harsh environment use of polymeric materials as encapsulants or base materials is described.

Next-Generation PPS Grades for Power Module Applications
Christian Schirmer, Yuki Ota, Toray Resins Europe , D
Greater toughness is sought in PPS (Polyphenylene Sulfide) electrical housings to enable simplified assembly procedures. The development uses proprietary Nanoalloy compounding technology to enhance the mechanical properties of the PPS compounds. This effort seeks to balance tradeoffs in formulation to maintain comparative tracking performance (CTI 600V) while increasing toughness

SiC based Power Module

New SiC 1200V Power MOSFET & Compact 3.25 mOhm, 41mm Power Module for Industrial Applications
Jeffrey Casady, Shadi Sabri, Sei-Hyung Ryu, Ty McNutt, Brett Hull, Brice McPherson, Sayan Seal, Jennifer Stabach, Austin Curbow, Dan Martin, Zach Cole, Brandon Passmore, Alex Lostetter, Scott, Allen, John Palmour, Wolfspeed - A Cree Company, USA
For the first time, a new SiC chip & module combination is designed and characterized for optimal performance and cost. The chip is a 1200V, 13m? SiC MOSFET designed for a ½ bridge power module with no need for individual RG inside the module, improved shoot-through immunity, low RDSON of 23m? at 175°C, and low CRSS of 12pF. The compact 41mm module allows up to four MOSFETs per switch, IDS rating of 340A (~ 7x higher than Si baseline modules) and lower RDSON (3.25m?) than commercial SiC modules over twice its size.

A Wire-bond-less 10 kV SiC MOSFET Power Module with Reduced Common-mode Noise and Electric Field
Christina DiMarino, CPES, Viriginia Tech, Blacksburg, USA; Ke Li, Bassem Mouawad, Mark Johnson, University of Nottingham, UK
While wide-bandgap devices offer many benefits, they also bring new challenges. The new 10kV SiC MOSFETs can switch higher voltages faster and with lower losses than silicon devices while also being smaller in size. In order to fully utilize the benefits of these unique devices, this work proposes a module package with high power density (18W/mm3), increased partial discharge inception voltage (67%), low thermal resistance (0.38K/W junction-to-ambient), small inductance (4nH), fast switching (200V/ns), and reduced common-mode noise (50%).

Enhanced Breakdown Voltage and High Current of All-SiC Modules with 1st Generation Trench Gate SiC MOSFETs
Motohito Hori, Yuichiro Hinata, Katsumi Taniguchi, Masayoshi Nakazawa, Yoshinari Ikeda, Tomoyuki Yamazaki, Fuji Electric, J; Thomas Heinzel, Fuji Electric Europe, D
In order to expand the application range of Silicone Carbide (SiC), SiC modules with 1st generation trench gate SiC MOSFETs from small capacity to large capacity were developed. This paper presents the package technologies of enhanced breakdown voltage and high current for All-SiC modules.

Highly Integrated SiC-power Modules for Ultra-Fast Lithium Ion Battery Chargers in LLC-Topology
Thomas Blank, Bao Ngoc An, Dominik Bauer, Patrick Jochem, Matthias Luh, Helge Wurst, Marc Weber, Karlsruhe Institute of Technology, D
A compact version of a SiC LLC converter for ultra-fast-charging of lithium-ion batteries is presented. The module can deliver a power of 40 kW, paralleled up to 350 kW. The system has been designed for highest reliability in a 24h/7d scenario. An Aurix processor controls the system. The SiC power devices are integrated in an Econopack 2, utilizing Si3N4 substrates, silver sinter die attach and CuCoreAl bonding technology. The LLC resonant tank is immersion cooled. Hence, a reliable, highly integrated ultra-fast charging system is realized.

Traction Inverters

Effects of a SiC TMOSFET Tractions Inverters on the Electric Vehicle Drivetrain
Alexander Nisch, Christian Klöffer, Jörg Weigold, Wolfgang Wondrak, Daimler, D; Christian Schweikert, Laurent Beaurenaut, Infineon, D

Due to the constantly increasing demand for the electrical range and to the restricted installation space, the request to the energy efficiency of a traction inverter will increase. Silicon carbide MOSFETs are considered as the most promising semiconductor devices for future traction inverter applications. In the presentation we discuss the potential and challenges of a three-phase voltage-source-inverter based on trench SiC MOSFET under automotive constraints, considering the complete drivetrain.

Highly Integrated Traction Inverter for a Modular Drive Concept
Ulf Schümann, Jasper Schnack, Ronald Eisele, Dominik Hilper, University of Applied Sciences Kiel, D; Christian Mertens, Patrick Heumann, Volkswagen, D; Hans-Jürgen Schliwinski, Malte Päsler, Jörn Hinz, Fraunhofer Institute ISIT, D; Mathias Kamprath, A
The growing demand of electrification in automotive powertrains requires an adapted, efficient, compact and cost-effective drive topology depending on the vehicle class. In the context of a research project, a novel design for an integrated traction inverter is developed which provides a scalable modular drive train. The paper gives a closer look to the integration approach by describing the development of the inverter components, aiming to reach a power density of 100kW/l.

Automotive Traction Inverter Utilizing SiC Power Module
Masaharu Nakanishi, Kenji Hayashi, Akifumi Enomoto, Masashi Hayashiguchi, Motohiro Ando, Kazuhide Ino, ROHM, Ltd, J ; Aly Mashaly, Christian Felgemacher, Guenter Richard, ROHM Semiconductor, D
In recent years, the market expansion of Silicon Carbide (SiC) power transistors has been started. We have seen a lot of improvements such as higher efficiency circuit and system miniaturization. EV/HEV/PHEV application has variety of usage for SiC Power devices. This paper focuses on to describe the benefits of newly developed high current/low stray inductance SiC Power Module and the optimizations of its SiC power module utilized traction inverter by comparing with conventional technology based traction inverter performance.

Novel Approach of Integrated Motor-Inverter Power Module for 48V Mild Hybrid Starter and Generator (MHSG)
Jihwan Seong, Sangwon Yoon, Minki Kim, Jangmook Lim, Hobeom Han, Hanyang University, ROK; Semin Park, Hyunkyu Choi, Yucheol Park, Pilkyoung Oh, Sang Min Kim, Taesuk Kwon, Hyundai Mobis, ROK
This paper newly presents power-module design aiming to integrate a motor and inverter in a single package. The integrated motor-inverter concept is specialized for a 48V mild hybrid starter and generator (MHSG) system in vehicle. This DBC-based integration reduces system size/volume, system parasitic inductance/resistance, and thermal resistance. These advantages are validated by using multi-physics finite element method (FEM) simulations, and experiments, exhibiting notable decreases in system inductance and peak voltage

Intelligent Motion

Decentralized Control of a Twelve-Phase PMSM
Oliver Dieterle, Thomas Greiner, University of Applied Sciences Pforzheim, D
This paper presents a decentralized current control for a twelve-phase permanent magnet synchronous machine. The phases of the considered machine are interconnected as four sets of each 3 star-connected phases. The machine has double-layer windings, which leads to a certain magnetic

coupling between coils that share one slot. In order to decide, if a decentralized control is satisfying, it is necessary to analyze the impact of the coupling. Furthermore, the proposed control is tested experimentally.

Computationally Efficient Predictive Direct Torque Control Strategy for PMSGs Without Weighting Factors
Mohamed Abdelrahem, Hisham Eldeeb, Christoph Hackl, Ralph Kennel, Technical University of Munich, D; Jose Rodriguez, University Andres Bello, CL
Nowadays, the availability of high-voltage Silicon Carbide (SiC) devices makes possible to redesign the classical multi-stage DC-AC photovoltaic (PV) converters in order to reduce inverter complexity and costs, while improving reliability. Having this in mind, the Current Source Inverter (CSI) is proposed. In this paper, the operation of a new 1.7kV full-SiC voltage bidirectional power module suitable for PV CSI applications is discussed. From experimental switching characterization results, the tradeoff between switching losses and EMI behavior is analyzed. Then, based on the estimation of semiconductor efficiency and thermal limits, the main design guidelines for a 70kW (60kHz) CSI are given. Furthermore, the inverter operation is discussed under two different grid voltage levels (690V_ac and 800V_ac).

Switching Frequency Control for a DS-PWM
Axel Klein, Malte Thielmann, Walter Schumacher, Technical University of Braunschweig, D
In 2014 Homann and Schumacher presented a new PWM-Modulator (ΔΣ-PWM). This hysteresis based modulator allows to fully utilize the advantages of the delta sigma signal processing (DSSP). Because of the hysteresis based switching cycle of the (ΔΣ-PWM) one main feature is a variable switching frequency. In this paper a method for controlling the average switching frequency will be presented. The paper will finish with an experimental verification of the concept.

Improvements on a Sensorless Controlled Synchronous Reluctance Machine Down to Standstill
Mario Nikowitz, Matthias Hofer, Manfred Schrödl, Technical University of Vienna, AT
In this paper a position - sensorless controlled syn. reluctance motor (SynRM) is discussed. The improvements on the sensorless behaviour are reached by using a high PWM frequency to reduce ripple current in the dc-link. This approach reduces the losses in the capacitors and provides a silent operation of the sensorless method. In order to realize that sensorless control it is necessary to reduce current sensing noise as well and improve the observer behaviour by implementation of a non-linear observer of the mechanical system.

SiC Devices I

A 3.3 kV/800 A Ultra-High Power Density SiC Power Module
Takashi Ishigaki, Seiichi Hayakawa, Tatsunori Murata,Toshihito Tabata, Katsuyuki Asaka, Koyo Kinoshita, Tetsuo Oda, Kan Yasui, Toshiaki Morita, Daisuke Kawase, Yuji Takayanagi, Renichi Yamada, Katsuaki Saito, Hitachi Power Semiconductor Device, J; Toru Ma
A 3.3 kV/800 A SiC power module was developed adopting the next High Power Density Dual (nHPD2) package. The ultra-high power density value of 37.7 kVA/cm2 was realized by constituting the module with only SiC-MOSFETs. Furthermore, as a countermeasure for "bipolar degradation" issues of body diodes in SiC-MOSFET, we also deployed new high-throughput screening process technology. The low-loss and high reliability characteristics of the module are demonstrated.

Efficiency Investigation of Full-SiC versus Si-based Automotive Inverter Power Modules at Equal Commutation Speed
Ajay Poonjal Pai, Tomas Reiter, Infineon Technologies, D; Martin März, Fraunhofer Institute IISB, D
This paper investigates the mission profile efficiency performance of a 1200V full-SiC Trench-Mosfet Module based on Infineon’s Automotive CoolSiCTM technology, suitable for traction inverter

applications. This module is compared against a full-Silicon (Si) module with Si Insulated Gate Bipolar Transistors (IGBTs)/diodes, and a hybrid Silicon Carbide (SiC) module with Si IGBTs and SiC diodes.

Applying the 2D-Short Circuit Detection Method to SiC MOSFETs Including an Advanced Soft Turn Off
Patrick Hofstetter, Stefan Hain, Mark-M. Bakran, University of Bayreuth, D
Nominated for the Young Engineer Award
To address the problem of small short circuit withstand times of SiC MOSFETs, this paper presents a short circuit protection, which detects the fault close to the earliest time possible and turns off the device safely. For the detection, the 2D-short circuit detection method was adapted to SiC MOSFETs. As SiC MOSFETs have to be turned off softly, a turn off strategy is shown which is able to turn-off the device during a short circuit type 1 and a short circuit type 2 in an optimized way.

Advanced Packaging Technologies I

Investigation of Ton Dependency of Al-Clad Cu Bond Wires Under Power Cycling Tests
Nan Jiang, Josef Lutz, Chemnitz University of Technology, D; Benjamin Fabian, Marko Kalajica, Heraeus, D
In the previous studies, power cycling tests with different junction temperature swings were performed for the Al-clad Cu wires, and significant improvements of the power cycling capability was observed. In this work, power cycling tests with different switch on time were performed for the Al-clad Cu wires. Similar on-time dependency of Al-clad Cu wires compared with aluminium wires was observed.

System Cost Reduction with Integration of Shunts in Power Modules in the Power Range Above 75 kW
Klaus Vogel, Michael Gadermann, Andreas Schmal, Christoph Urban, Infineon Technologies, D
Cost reduction and increased power density at high lifetime level are the main challenges for the development of new inverter generations. For instance, the electrical performance of IGBTs and diodes has been improved constantly in addition to improved interconnection technologies. A further potential for cost reduction is the introduction of shunts for current measurements in the power modules, replacing hall sensors in the AC bus bar in the inverter power range above 75 kW.

Cost Effective Direct-Substrate Jet Impingement Cooling Concept for Power Application
Bassem Mouawad, Robert Abebe, Robert Skuriat, Jianfeng Li, Liliana De Lillo, Lee Empringham, C. Mark Johnson, University of Nottingham, GB; Andy Roberts, Robert Clarke, RAM Innovations, GB, Geoff Haynes, Inspirit Ventures, GB
This work demonstrates a cost-effective manufacturing approach based on the printed circuit board technology to create the impingement cells under direct bonded copper substrate. Results from both computational fluid dynamics simulation and transient thermal test verify the good performance of such jet impingement cooling system under high power density conditions.

Power Electronics Topologies

Protection Schemes in Low-Voltage DC Shipboard Power Systems
Seongil Kim, Drazen Dujic, EPFL - Ecole polytechnique fédérale de Lausanne, CH; Soo-Nam Kim, Hyundai Electric, ROK
Shipbuilding industry has increased interest into DC shipboard systems due to their main benefits. These new power systems come with technical challenges in system protection owing to low thermal capability of semiconductor devices. This paper presents feasible protection schemes against DC short circuit faults for three different types of, commercially available, LVDC rectifier systems. A novel protection method by means of an artificial three-phase short circuit on AC-side is also proposed for the active rectifier.

Power Stage and Control Design of A 60-kV 60-kW Switching Power Supply for
Shengwen Fan, Yiqin Yuan, Zhenyu Shan, Pengyu Jia, Zhengxi Li, Yinghong Li, Yongchang Zhang, Guofeng Yuan, North China University of Technology, CN
This paper presents the design of a high-voltage power supply for electrostatic precipitator (ESP) applications. The topology of the power stage in this work is a quasi-resonance LC converter with multiple inverter circuits and voltage multipliers, and the control design is based on a small-signal model of the power stage. Two sets of proportional-integral (PI) control parameters are designed for full-load and light-load situations according to the smallsignal model that is derived with a modeling method proposed for LC converters. The power stage and control design are verified by simulations and a prototype.

Design of a three-phase 70kW Current Source Inverter for Photovoltaic Applications Using a New 1.7kV Full-SiC Voltage Bidirectional Power Module
Luis Gabriel Alves Rodrigues, Jérémy Martin, Anthony Bier, Stéphane Catellani, Commissariat à l´Énergie Atomique et aux Énergies Alternatives, F; Jean-Paul Ferrieux, University Grenoble Alpes, F
The availability of high-voltage Silicon Carbide (SiC) devices makes possible to redesign the conventional multi-stage photovoltaic (PV) inverters in order to reduce complexity and costs, while improving reliability. Having this in mind, the Current Source Inverter (CSI) topology is proposed. In this paper, the operation of a new 1.7kV full-SiC power module suitable for PV CSI applications is discussed. From experimental results, the main design guidelines for a 70kW (60kHz) CSI are given, considering two different grid voltage levels (690Vac and 800Vac).

Multi-Level Converters

Modular Multilevel Converters as Active Filters to Mitigate Low Frequency Current Harmonics in Converter Fed Grid Applications
Dennis Bräckle, Stefan Mersche, Mathias Schnarrenberger, Patrick Himmelmann, Marc Hiller, Karlsruhe Institute of Technology (KIT), D
In grids with decentralized energy production and bidirectional power flow, an increasing numbers of power electronic loads makes power quality an important issue to ensure grid stability. The MMC is highly suitable to meet the requirements of a low Total Harmonic Distortion and voltage stability due to its high quality output voltages. MMCs compensate low frequent grid harmonics. A standalone laboratory scale converter-fed microgrid shows the capability of the developed control algorithms.

MMC-Based High Power DC-DC Converter Employing Scott Transformer
Stefan Milovanovic, Drazen Dujic, Power Electronics Laboratory, EPFL, CH
So far, Scott Transformer has mostly been employed in the railway applications in order to obtain two separate single-phase AC voltages out of one three-phase voltage source. This paper proposes bidirectional, isolated, high-step down, MMC-based, DC-DC converter intended to connect medium voltage and low voltage DC grids. In order to achieve galvanic separation between medium voltage and low voltage sides of the converter, Scott Transformer was used.

Experimental Validation of Three-Level Advanced-Active-Neutral-Point-Clamped Converter for Grid Operation
Sidney Gierschner, Felix Kayser, David Hammes, Yves Hein, Hans-Günter Eckel, University of Rostock, D; Diemtar Krug, Siemens, D
The three-level AANPC converter represents a multilevel converter with a fault-tolerant behaviour. Furthermore, it has a high degree of modularity. This aspect can be advantageous for the next generation power semiconductor modules. This paper presents the experimental validation of the three-level Advanced-Active-Neutral-Point-Clamped converter for grid operation at safety extra-low voltage level. Also, the interaction of a microcontroller and a FPGA for control and modulation purposes is explained.

Energy Storage

Megawatt Scale Li-Ion Batteries Mounted in Opposition to Save Power During Test
Younès Jaoui, Philippe Laflaquiere, Carlos Santaolalla, Cyril Monnoyer, Cedric Alnet, SAFT, F
After an accurate job from Engineering, Industrial , Prototype and Testing teams, and multiple meetings dedicated to risk analysis and safety consideration the dream came true and a 3MW container has been cycled under power equivalent to 2,3MW charge / discharge. The battery voltage was close to 800V, thermal power inside the container equivalent to 2.3MW electrical cycles, while the test bench was delivering only 50kW power representative of joule losses within the cells.

A Battery Cell Emulator for Hardware in the Loop Tests of Reconfigurable Lithium-Ion and Post-Lithium Batteries
Simon Bischof, Cem Kücük, Thomas Blank, Marc Weber, Karlsruhe Institute of Technology (KIT), D
A modular battery emulator for reconfigurable battery topologies is presented. The battery emulator is based on linear controllable power electronic boards, which are used to emulated cells with lithium-ion or post-lithium cell chemistry. The individual emulation boards can be connected in series as well as in parallel. Each cell can source and sink currents up to 6 A. The final design will increase this to 18 A.

Combined Sensor Minimal Cell-Monitoring and Active Inductive or Capacitive Cell-Balancing
Philip Dost, Constantinos Sourkounis, Ruhr-University of Bochum, D
A new balancing system that allows to transfer energy between any two cells with high efficiency and least amount of battery load, while this system likewise allows monitoring of all cells individually without additional wiring is presented. With two realisation options it allows a voltage based balancing in the capacitive mode or balancing based on any (fictive) characteristic curve (e.g. SoC) in the inductive mode. In addition, module balancing can easily be applied to the system.

MOSFET and IGBT

A New MOSFET Intelligent Power Module for Low Power Motor Drive Applications
Jaewook Lee, Junbae Lee, Daewoong Chung, Infineon Technologies Power Semitech, ROK
This paper introduces a new MOSFET CIPOSTM (Control Integrated Power System) Mini which is the IPM (Intelligent Power Module) that integrates 650V rated CoolMOSTM MOSFETs with fast body diode, a SOI (Silicon On Insulator) gate driver with 6 channels and protection circuit in a DIL (Dual-in-line) fullpack package with transfer molded type. Especially, this module offers high efficiency under the low power motor drive application such as refrigerator in home appliances. This paper provides an overall description of the new MOSFET IPM.

High Voltage Semiconductor Switch on the Base Of RCRSD for Bipolar Power Current Pulse Commutation
Alexey Grishanin, Alexey Khapugin, Valentin A. Martynenko, Vyacheslav Muskatinev, Vyacheslav Eliseev, Oleg Frolov, JSC Electrovipryamitel, RU; Sergey Korotkov, Ioffe Physico-Technical Institute, RU; Igor Galakhov, Vladimir Osin, Institute of Laser-Physica
The paper presents development results of new semiconductor device - reverse conducting reverse switched dynistor RCRSD and high effective discharge switch for bipolar power current pulse commutation on the base of this device. It was found by experimental investigation of RCRSD that it is capable to commutate bidirectional current pulses in hundreds MW range. Power loss in RCRSD during reverse current pulse commutation is 2-fold lower than that in RSD.

IGCT Switching Behaviour Under Low Current Conditions
Dragan Stamenkovic, Drazen Dujic, EPFL - Ecole Polytechnique Fédérale de Lausanne, CH; Umamaheswara Reddy Vemulapati, Munaf Rahimo, Thomas Stiasny, ABB Semiconductors, CH
IGCT Switching Behaviour Under Low Current Conditions
M.Sc. Dragan Stamenkovic, EPFL, Lausanne, Schweiz

Given the typical operating conditions and the design practices, IGCT manufacturers have paid little attention to the switch's behaviour under low load and this information is mostly absent in the datasheets. Low current turn-off of the IGCT is explored throughout this paper, supported by TCAD simulations and test results from a dedicated test setup. Initial tests show the extended duration of the turn-off process as the turn-off current decreases, which must be taken into account during design.

LV100 High Voltage Dual Package in Paralleling Operation
Ryo Tsuda, Nils Soltau, Eugen Wiesner, Eckhard Thal, Mitsubishi Electric Europe, D; Shinichi Iura, Tetsu Negishi, Mitsubishi Electric Corporation, J
MITSUBISHI ELECTRIC has announced LV100-package [1] [2]. This new package is considered as standard for traction application suitable for using with Si and SiC chips. To achieve inverter scalability, LV100-package also focuses on parallel connection. The paralleled modules influence the inverter performance due to required derating. Besides external boundary conditions, like DC-link bus bar and gate driver, the electrical module parameters themselves have strong impact on the inverter derating. Therefore, this paper analyzes the influence the electrical parameters, in particular the diode parameters, on the required module derating. Furthermore, an outlook on paralleling future SiC-based diodes is given.

MOSFET Technologies for Auxiliary DC-DC Converters
Filippo Scrimizzi, Filadelfo Fusillo, STMicroelectronics, I
ST High Voltage and Low Voltage MOSFET technologies (DM6 and F7) represent the best solution for primary side switches and synchronous rectifiers in bi-directional auxiliary DC-DC converters widly used in EV/HEV market, optimizing the system design and enhancing the overall performance.

SuperJunction Power Device Evolution: Characteristics Analysis and Performance Comparison of MDmesh? M2 and MDmesh? M6 Technologies
Antonino Gaito, Maurizio Melito, Santina Leo, STMicroelectronics, I
When we consider Super Junction devices and it was experimentally observed that Crss does not decrease monotonic by increasing Vds. This paper studies this phenomenon introducing a simplified mathematical model which explains the Crss behaviour in SJ power MOSFETs.

Dynamic Current Sharing and Gate Feedback During Turn-OFF of Paralleled IGBTs
Robin Schrader, Patrick Münster, Hans-Günter Eckel, University of Rostock, D
Current redistributions occur during turn-OFF of paralleled IGBTs. This effect has been observedby measurements and simulations before. Though, this paper explains the physicalredistribution mechanism in detail. The process of this redistributions is defined by the electronand hole currents in the IGBTs, their gate- and collector-emitter voltages and by their influenceon each other. The redistributions end, when the collector-emitter voltages reach the dc-linkvoltage.

Evaluation of Miller Capacitance Depending on Drain-Source Voltage When SJ HV Power MOSFETs are in Reverse Mode
Carmelo Parisi, Domenico Murabito, Valeria Cinnera Martino, Yosef Damante, Antonio Giuseppe Grimaldi, STMicroelectronics, I; Giuseppe Consentino, University of Calabria, I
Each power application has its own requirements and optimization criteria which are reflected in the available technologies paired with innovative package solutions. It is very difficult, if not even impossible, to fulfill at the same time driving factors like efficiency, power density, EMI, layout parasitic elements, commutation behavior and cost so it is necessary to lead different technologies and solutions. But the advantages of introducing a new technology may not emerge if you do not adopt both circuitry and layout design criteria that take into account the peculiarity of the new devices. Particular attention must be paid when increasing switching speeds because intrinsic differences between capacities and how they interact with parasitic components of the circuit can lead to undesired results. The purpose of the work is to highlight the main characteristic that differentiate the

two SJ technologies, as the well-known M2 and the new comer M6, suggesting the guidelines that allow you to choose the one that best fit the application needs.

Characterization of Voltage Divergence in Series Connected SiC Trench MOSFETs and Si IGBTs
Zarina Davletzhanova, Olayiwola Alatise, Jose Ortiz Gonzalez, Tianxiang Dai, Roozbeh Bonyadi, University of Warwick, GB
Series connected power devices are required for voltage sharing in HV applications like grid connected converters and dc circuit breakers. The impact of power device technology on voltage sharing in series devices is important to enable snubberless operation via active gate control. This paper investigates voltage sharing in series connected devices by comparing SiC trench MOSFETs and Si IGBTs. Measurements and FE models have been used for evaluating the impact of electrothermal variation (temperature and switching rate) on voltage imbalance

SiC and Silicon MOSFET Solution for High Frequency DC-AC Converters
Luigi Abbatelli, Cristiano Gianluca Stella, Giuseppe Catalisano, STMicroelectronics, I
Multichannel Voltage Source DC/AC Inverter are used to supply heater elements such as IR Halogen Lamps to be integrated in the Power Architecture of oncoming 3D Printers. A comparison with silicon device's state of art is made: electrical and thermal performances of three main transistors families (650V SiC MOSFET devices, 650V Silicon MOSFET and 650V Silicon IGBTs) are evaluated where the new 650V SiC MOSFET is in used as switch in the inverter high frequency leg and the 650V silicon MOSFETs/IGBTs are in used in the line frequency leg.

Short Circuit Robustness Improvement by FEM Simulation on IGBT
Daniela Cavallaro, Rosario Greco, Gaetano Bazzano, STMicroelectronics, I
A Finite Element Model has been used to simulate the thermal behavior of a HV IGBT during a Short Circuit Test (SCT) using front and back metal “cooling” solutions. The purpose is to evaluate by simulations if the proposed solution can improve the robustness of the device during the SCT. The electrical simulation conditions have been experimentally obtained by reproducing in laboratory the failure of the power sample device during the SCT.

A New Combined VGE and VCE Based Short-Circuit Detection for High-IC,desat HV-IGBTs and RC-IGBTs
Julian da Cunha, David Hammes, Jan Fuhrmann, Daniel Lexow, Hans-Günter Eckel, University of Rostock, D
Measurements are made to validate a already proposed 1-D gate-emitter voltage based short-circuit (SC) detection and enhancements leading to a new 2-D UGE and UCE based detection method are being proposed and validated.Different HV-IGBT driver setups will further be compared in respect to their SC-detectionmethods ability to protect low conduction loss optimized HV-IGBTs from destructionin the event of a fault as well as to measure the current direction through the module for RC-IGBT applications.

SiC Devices

Analog Based High Efficiency 2KW Totem Pole PFC Converter Using Surface Mount SIC MOSFET’s
Jianwen Shao, Guy Moxey, Cree, USA; Binod Agrawal, Venkata Subash Bathula, Navneet Mangal, Cree, IN;
Implementation of a Low-cost totem pole power factor correction (PFC) converter using SiC MOSFETs is presented in this paper. First, a new current sensing scheme is presented which enables cost effective analog controllers to be used for totem pole PFC converters. Secondly, it has been implemented to design and test a 2KW totem pole PFC converter using Cree 900V, surface mount MOSFET.

Switching Pattern and Performance Characterization for "SiC+Si" Hybrid Switch
Haihong Qin, Qiang Xiu, Dan Wang, Shishan Wang, Nanjing University of Aeronautics and Astronautics, C; Chaohui Zhao, Shanghai DianJi University,CN
This paper presents the static and dynamic performance of paralleled 1.2kV SiC MOSFET and 1.2kV SiC IGBT and compares them with a full Si IGBT and a full SiC MOSFET reference devices having the same power ratings as for the hybrid samples. The hybrid parallel connection aims to reach optimum power device performance by providing low static and dynamic losses .Considering the different switching speeds and output characteristics of SiC and Si devices in such hybrid structure, the sequence of switching should be controlled to enable the Zero Voltage Switching (ZVS) for Si IGBTs. Test results are obtained to validate this approach with respect to the static and dynamic performance.

Driver Integrated Fault-Tolerant Reconfiguration after Short-On Failures of a SiC MOSFET ANPC Inverter Phase
Michael Gleißner, Teresa Bertelshofer, Mark-M. Bakran, University of Bayreuth, D
Fault-tolerant converters are required for applications with a high risk of damage or financial loss. The fault-tolerant ANPC inverter enables an ongoing degraded operation after single switch failures, if no secondary failures occur. This paper investigates the critical failure scenarios of a single-phase ANPC prototype built with 650 V SiC MOSFETs. Innovative driver integrated measures for immediate short-circuit detection, overvoltage clamping and switching strategy reconfiguration in order to enable a reliable ongoing operation are shown.

SiC Effect on Surge Voltage Distribution in Large Electrical Machines
Robert Maier, Mark-M. Bakran, University of Bayreuth, D
This paper investigates the impact of fast SiC switching transients on the voltage distribution of coil and winding voltages. The hardware under investigation is a stator with preformed coils and tapped windings. The rated power is in a range of 200 kW. The final paper will contain measurements that demonstrate the impact of varying rise times including feeding cable effects.

Junction Temperature Measurement of SiC MOSFETs: Straightforward as it Seems?
Tobias Kestler, Mark-M. Bakran University of Bayreuth, D
Reliable measurement of the junction temperature Tj is essential for the application of power semiconductors. Similar to the IGBT's Vce-method, for SiC MOSFETs the voltage drop over the body diode can be used for Tj acquisition. This method is validated for different devices with consideration of the gate voltage's and measuring current's influence. Furthermore the applicability of the Rgi-Method, which also works in switching operation, gets evaluated for SiC MOSFETS.

In-Depth Study of Short-Circuit Robustness and Protection of 1200V SiC MOSFETs
Xuning Zhang, Levi Gant, Gin Sheh, Sujit Banerjee, Monolith Semiconductor, USA
This paper presents in-depth study of short circuit capability of 1200V SiC MOSFETs under different conditions with explanation and design trade-offs from both application and device stand point. Performance of different off the shelf gate drive ICs with de-sat protection functions are compared and short circuit protection in half bridge configuration are discussed. Finally, a gate drive design is demonstrated that can protect 1200V SiC MOSFETs under real life short circuit conditions.

Avalanche Rugged Low On-Resistance 1200V SiC MOSFETs With Long-Term Stability
Kwangwon Lee, ON Semiconductor, KR, Martin Domeij, Jimmy Franchi, Benedetto Buono, Fredrik Allerstam, ON Semiconductor, SE; Thomas Neyer, ON Semiconductor, D
1200V SiC MOSFETs with low on-resistance (Rsp=4.4mohm.cm2) were fabricated on 6 inch wafers and characterized to assess the device ruggedness and reliability. The wafer level unclamped inductive switching (UIS), negative bias threshold voltage stress, and high temperature reverse bias

(HTRB) stress tests were conducted and good avalanche ruggedness statistics was shown and improved VTH stability during negative bias stress was found compared to three similarly rated commercially available SiC MOSFETs.

High Performance 4H-SiC MOSFETs with Optimum Design of Active Cell and Re-Oxidation Process
Toshikazu Tanioka, Yuji Ebiike, Yasunori Oritsuki, Masayuki Imaizumi, Masayoshi Tarutani, Mitsubishi Electric Corporation, J
We present latest high performance 4H-SiC planar MOSFETs. By applying a cell structure with JFET doping, the newly designed 1200V class MOSFET has exhibited very low specific on-resistance (Ron,sp) of 3.0 mΩ·cm2 at 25 °C. We have also fabricated the high threshold voltage (Vth~4.9V) 600V class SiC-MOSFET with the optimized cell structure by using re-oxidation technique.

Derating of Parallel SiC MOSFETs Considering Switching Imbalances
Teresa Bertelshofer, Andreas März, Mark-M. Bakran, University of Bayreuth, D
This paper presents a numerical method to analyse the parallel connection of SiC MOSFET dies. The effect of asymmetries within the chips' parameters, especially the threshold voltage, is investigated. The investigation result quantifies, to what extent the PTC behaviour of the Ron can mitigate the overheating of one chip caused by switching loss imbalance. The results are used to define a necessary derating of the inverter output power, so that no single chip is thermally overstressed.

Commutation Characteristics During Switching of Hybrid SiC and Si Configurations
Michael Schütt, Hans-Günter Eckel, University of Rostock, D
This paper presents the switching characteristics for hybrid configurations of SiC and Si switching devices. This work shows the effect of higher displacement currents on switching attributes due to higher blocking capacitance and shorter switching times of SiC elements. This paper studies the current commutation between the body diode of a SiC-MOSFET and a SiC-SBD during switching. Further, this work extends on the hybrid configuration of a Si-IGBT and a SiC-MOSFET with an antiparallel SiC-SBD.

Current Sharing During Unipolar and Bipolar Operation of SiC JBS Diodes
Thomas Barbieri, Adam Barkley, James Solovey, Edward van Brunt, Edgar Ayerbe, Wolfspeed, USA
Commercial SiC JBS diodes operate as unipolar devices under standard conditions, allowing for uniform current sharing and easy paralleling. Under transient surge conditions, these diodes can transition into bipolar operation, where uniform current sharing is not expected to occur. This work evaluates the non-uniform current sharing behavior of JBS diodes in parallel as they transitioned into bipolar mode. Recommendations are made for safe operating area for current surge in parallel diodes.

Ruggedness Behavior of SiC JBS Diodes and SiC MOSFET Body Diodes Under Extreme Short Circuit Conditions
Mehrdad Baghaie Yazdi, Thomas Neyer, ON Semiconductor Germany, D; Andrei Konstantinov, Martin Domeij, ON Semiconductor, SE
In this paper we study the ruggedness of silicon carbide JBS Diodes and the Body Diodes of SiC MOSFETs under extreme surge currents conditions. For this a new kind of surge current tester has been designed capable of generating sinusoidal surge currents with pulse widths ranging from a few hundreds of nanoseconds to millisecond. The effect of such surge currents is investigated with resepct to the degredation and destruction point of various devices.

GaN Devices and Applications

Application of GaN-GITs in a Single-Phase T-Type Inverter

Carsten Kuring, Jan Böcker, Sibylle Dieckerhoff, Jonas Lenth, Tino Kahl, Technical University of Berlin, D
Power electronics applying GaN semiconductors are promising high efficiency enabled through increased switching frequency and minimized switching losses. Fast switching demands for minimized stray inductances but contradicts the concept of the T-type inverter. While power semiconductors experience similar electrical stress inside the T-type and half-bridge topology, thermal performance is a limiting factor. Despite increased number of semiconductors in the T-type inverter an efficiency of appr. 99% is achieved at 150 kHz switching frequency.

S-Parameter Characterization of GaN HEMT Power Transistors for High Frequency Modeling
Loris Pace, Arnaud Videt, Nadir Idir, University of Lille - L2EP, F; Nicolas Defrance, Jean-Claude Dejaeger, IEMN
Gallium Nitride (GaN) power devices developed these recent years are ideal candidates for high frequency power conversion, leading to a reduction of size, cost and weight of power converters. The design of these converters is based on simulations which require developing accurate models over a wide frequency range. This paper presents a new characterization method of GaN power transistors based on the extraction of devices small-signal parameters up to the gigahertz range using 2-port S-parameters measurements and dedicated characterization fixtures on printed circuit boards (PCB).

650V E-Mode GaN HEMT Switching at 1MHz for Travel Adapter Applications
Ann Starks, Zhiyang Chen, Mike Cargile, ON Semiconductor, USA
This paper presents the characteristics of the 650V Enhancement-mode gallium nitride (E-GaN) high-electron mobility transistor (HEMT) from ON Semiconductor Corporation. It demonstrates 1MHz frequency application in a travel adapter. A flyback converter topology is used in the travel adapter application. The driver circuit for 1MHz switching frequency for E-GaN HEMT is presented and experimental results show that high efficiency is achieved in the new design with the 650V E-GaN HEMT.

Power p-GaN HEMT Under Unclamped Inductive Switching Conditions
Juraj Marek, Alexander Šatka, Martin Jagelka, Aleš Chvála, Patrik Príbytný, Martin Donoval, Daniel Donoval, Slovak Technical University in Bratislava, SK
In our work we present the results of Unclamped Inductive Switching (UIS) measurements of power GaN HEMTs comprised of p-GaN gates. Typical test waveforms and basic description of effects during discharging period of inductor are presented and discussed. It is experimentally confirmed that p-GaN HEMT devices exhibit even small intrinsic UIS capability that strongly depends also on driving circuit. Influence of different inductances as well as different supply voltage is also analyzed.

Designing High-Density Power Solutions with GaN
Paul Brohlin, Masoud Beheshti, Texas Instruments, USA
Gallium nitride (GaN) once thought of as just a cool new power FET technology, is now changing the way power supply engineers are designing for density and efficiency. GaN-based solutions not only make power supplies faster, smaller and cooler, but also meet industry's demand for ruggedness and system solution cost. This paper provides an in-depth insight into how GaN is making this possible, and is demonstrated with practical design examples.

Inverse Thermal Model of Temperature-to-Power Mapping for eGaN Systems
Shuangfeng Zhang, Eric Laboure, University of Paris, F; Denis Labrousse, Stéphane Lefebvre, ENS Cachan – SATIE, F
This paper deals with the problem of measurement of the losses in Power GaN chips due to the almost impossibility to measure the current under the penalty of adding parasitic inductances incompatible with the switching speeds of these components. For this purpose, this paper investigates the steady-state inverse heat conduction model (IHCM) developed from thermal simulations. The main

objective is to derive the power dissipated in a GaN chip mounted on or in a PCB from the surface temperature measured by infrared thermography.

High Performance Thermal Solution for High Power GaN?FET Based Power Converters
Michael de Rooij, Yuanzhe Zhang, David Reusch, Efficient Power Conversion (EPC) Corporation, USA; Sriram Chandrasekaran, Raytheon, USA
This paper explores a thermal cooling method suitable for small area eGaN FETs that eliminates mechanical stresses during assembly and yields excellent thermal performance using a liquid thermal interface material. A 140 V to 28 V Buck converter, capable of delivering 34 A (1kW) was designed and tested that resulted in nearly 5x increase in output current capability.

Wafer Level Embedding Technology for Packaging of Planar GaN Half-Bridge Module in High Power Density Conversion Applications
Charles-Alix Manier, Kirill Klein, Hermann Oppermann, Klaus-Dieter Lang, Felix Wüst, Robert Gernhardt, Fraunhofer-Institute IZM, D; Sophie Andzouana, Radoslava Mitova, Schneider Electric, F; Philippe Cussac, CIRTEM, F
A new fabrication process is presented for packaging of GaN bare devices in form of silicon-based packages using wafer level back-end processes. Compact planar half-bridge modules were fabricated at 200 mm wafer scale with 650 V rated single GaN bare die. The package demonstrates voltage breakdown up to 650 V with leakage current as low as 250 nA and thermal resistance RthJC of around 0.4 K/W. Implementation in power solutions has been first evaluated and results will be presented.

Monolithic GaN Power ICs Enable High Density High Frequency 3.2KW AC-DC Rectifier
Tom Ribarich, Dan Kinzer, Navitas Semiconductor, USA; Ruiyang Yu, Qingyun Huang, Alex Q. Huang, University of Texas at Austin, USA
A 3.2KW 240VAC-to-48VDC high-density rectifier has been designed, built and tested. The topology selected includes an interleaved totem-pole power factor correction (PFC) front end, a resonant LLC step down converter, and a synchronous rectification (SR) output stage. The power train consists of GaN Power ICs with integrated gate drive operating at frequencies of 1MHz and has enabled an overall power density target of 70 W/in3. The prototype has reached peak efficiencies of 99% in the PFC stage and 98.3% in the LLC/SR stage.

Experimental Study on Gate Drive Influence to the 650V GaN E-HEMT
Zhang Yi, Teng Liu, Yifan Tan, Cai Chen, Yong Kang, Huazhong University of Science and Technology, CN
The high voltage 650V GaN E-HEMT shows potential to achieve higher efficiencies and higher switching frequencies than possible with silicon MOSFETs. This paper will study and comprise three different gate drives: isolated negative voltage gate drive (INGD), isolated zero voltage gate drive (IZGD), bootstrap gate drive (BSGD) for 650V GaN E-HEMT (GS66508P from GanSystems). The gate resistor influence, bead influence under different common source inductance and small dead time influence at small current are tested for three gate drives.

SiC Power Modules

Switching Behavior of SiC-MOSFETs in High Power Modules
Florian Störmer, Hans-Günter Eckel, University of Rostock, D; Franz-Josef Niedernostheide, Frank Pfirsch, Infineon Technologies, D
To evaluate the switching behavior as well as switching losses in high power modules, a single chip 40 A SiC-MOSFET was tested with high commutating inductance. The single SiC-MOSFET need to slown down because of the increased oscillations and overvoltage during turn-off. To reduce these higher switching losses, new control concepts have been developed and tested.

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The Challenges of Using SiC MOSFET-Based Power Modules for Solar Inverters
Matthias Tauer, Vincotech, D
This paper examines SiC MOSFETs as a viable option for meeting the rising demand for faster switching and greater efficiency in 1500 V solar applications. It looks at their benefits - SiC MOSFETs enable deeper integration and greater power density - and their drawbacks in terms of switching performance and thermal conductivity in power module applications. The latest generations of devices' intrinsic properties appear to inhibit performance and reliability.

Low Inductive SiC Power Module Design Using Ceramic Multilayer Substrates
Thomas Huber, Alexander Kleimaier, University of Applied Sciences Landshut, D; Sebastian Polster, Olivier Mathieu, Rogers, D
This paper presents the module design of a novel 600 V / 200 A full silicon carbide (SiC) half-bridge inverter module. The module is realized with a ceramic multilayer substrate which allows an ultra-low power loop stray inductance value of 1.3nH. Thermal simulations reveal that the thermal resistance is not increased by the multilayer design. Due to the heat spreading within the copper layers, the thermal influence of an additional ceramic layer can be compensated.

Very Low Stray Inductance, High Frequency 1200V_ 2 mOhms Full SiC MOSFET Phase Leg Module
Serge Bontemps, Pierre Laurent Doumergue, Microsemi Power Module Products, F
This paper presents the characterization of a new 1200V / 2 mOhms Full SiC MOSFET phase leg module featuring a very low stray inductance within the standard 62 x 108 mm2 package. This module is built with an AlSiC base plate, AMB on Si3N4 substrates and the SiC MOSFET die are silver sintered for highest thermal performance and reliability. This 1200V/600A module achieves a parasitic inductance below 5 nH

Comparative Study of Full SiC Power Module in 1MHz, 600V, 50A Switching Operation
Kei Hayashi, Tsuyoshi Funaki, Osaka University, J; Hisato Michikoshi, Kenji Fukuda, National Institute of Adavnced Industrial Science and Technology, J
This paper develops 1200V, 50A full SiC half bridge power module, witch embeds C snubber and gate resistor. Embedded C snubber suppress surge voltage in fast switching operation, and gate resistors avoid parasitic gate oscillation of parallel connected SiC MOSFET in the module. 1MHz switching operation of developed module with 600V DC-Link voltage and 100A peak to peak load current is experimentally confirmed. In addition, two commercial power modules are applied with same test condition to evaluation developed power module.

3.3kV SiC Hybrid Module with High Power Next Core (HPnC) Package
Lukas Kleingrothe, Fuji Electric, D; Yusuke Sekino, Susumu Iwamoto, Akira Iso, Hideaki Kakiki, Yuichi Harada, Osamu Ikawa, Tomohiro Moriya, Fuji Electric, J
Recently main requirements for power conversion system are further downsizing and higher efficiency. To satisfy these requirements, enhanced power density of power modules should be the key to succeed. In this paper, 3.3kV SiC-Hybrid module with High Power next Core package, which can realize lower switching loss than Silicone, has been described.

High Reliable 1700V Full SiC Power Module
Kenji Hayashi, Yoshihisa Tsukamoto, Masaaki Matsuo, Masashi Hayashiguchi, Motohiro Ando, ROHM, J
1700V, 250A full SiC power module composed of Silicon Carbide (SiC) MOSFETs and SiC Schottky diodes has been launched. We utilized standard module package which is used in the market widely like as mass-produced ROHM's BSM300D12P2E001. Especially the 1700V full SiC module could pass over 1000 hours lifetime of HTRB and HV-H3TRB test. The ROHM's newly module has high reliability for usage in high humidity environment.

Analysis of 1200 V Si-SiC-Hybrid Switches for Resonant Applications
Michael Meissner, Sebastian Fahlbusch, Daniel Lüthke, Klaus F. Hoffmann, Helmut-Schmidt-University, D
Hybrid switches consisting of a silicon IGBT and a silicon carbide MOSFET are a promising approach forpower loss reduction in resonant topologies. Potentials and performance are analysed and discussed indetail.

Sintering Cu Paste Die-Attach for High TJ Power Devices
Shijo Nagao, Yue Gao, Akio Shimoyama, Katsuaki Suganuma, Osaka University, J; Shinichi Yamauchi, Takahiko Sakaue, Yoichi Kamikoriyama, Mitsui Mining & Smelting, J
Metal sintering paste of Cu submicron/micron-particles is considered as a heat-resistant die-attach material for emerging wide bandgap power semiconductors, with its excellent electrical and thermal conductivity as well as its affordability. In the present work, a Cu particles paste was used for die-attach of SiC-MOSFET. The specimens of sintered Cu bonding structure were subjected to high temperature storage test, thermal shock test and power cycle test. Long?term reliability of the bonding was evaluated by die-shear strength test, phase analysis, microstructure observation, and electrical resistance.

Advanced Power Modules

Influence of Auxiliary Gate and Emitter Connections on Short Circuit Behaviour of Multichip IGBT Modules
Helong Li, Chunlin Zhu, Paul Mumby-Croft, Yafei Wang, Daohui Li, Yangang Wang, Dynex Semiconductor, GB; Xiaoping Dai, CRRC Times Electric, CN
This paper investigates the influence of the auxiliary emitter and the gate connections on short circuit current behaviour of multichip IGBT power module. It reveals that the position of the auxiliary emitter connection has significant impact on the short circuit current of the power module. Experimental results validate the analysis of the short circuit current. The conclusion of this paper helps DBC layout design in terms of short circuit performance.

Impact of I2t Capability of RC-IGBT and Leadframe Combined Structure in xEV Active Short Circuit Survival
Hayato Nakano, Akihiro Osawa, Keiichi Higuchi, Akio Kitamura, Daisuke Inoue, Souichi Yoshida, Hiromichi Gohara, Masahito Otsuki, Fuji Electric, J
This presentation describes the new investigate results of s I2t capability for automotive IGBT power module used for xEV powertrain application. Experimental done with combination matrix of :(RC-IGBT or the conventional FWD) x (leadframe interconnection or bondwires), These results gives giant impact on vehicle safety in terms of much higher capability in active short-circuit failure mode, in which the inverter must open all-low side switches to protect batteries from abnormally high motor surge.

New Developed 3.3kV/1500A IGBT Module
Daohui Li, Ariful Islam, Yangang Wang, Fang Qi, Matthew Packwood, Paul Mumby- Croft, Dynex Semiconductor, GB; Xiaoping Dai, Haihui Luo, Guoyou Liu, Wei Zhou, CRRC Times Electric, CN
One set of new internal design and assembly process have been utilised into high power IGBT module with 140mmX190mm footprint. There are several key improvements for the module: (a) 3D busbar-substrate assembly has shown 40% less inductance than the traditional 2D structural busbars; (b) 12.5% reduction of IGBT?s thermal resistance and 25% reduction of FRD?s thermal resistance, (c) FRD performance has been enhanced, (d) ohmic losses from both metal busbars and metal layer of substrates are much lower for the new design.

Newly Developed 7th Generation 1,700V IGBT Module Product Family for Industrial Application

Takuya Yamamoto, Shinichi Yoshiwatari, Osamu Ikawa, Souichi Okita, D. Nagai, S. Miyashita, Y. Sakurai, Y. Onozawa, T. Ito, Fuji Electric, J; Thomas Heinzel, Fuji Electric, D
This paper describes newly developed 7th Generation 1,700V IGBT module. The 7th Generation 1,700V IGBT modules have been developed based on concepts of higher power density and higher reliability. To realize the concepts, many advanced technologies are applied such as power dissipation improvement by newly developed 7th generation IGBT and FWD Si dies, lower thermal resistance by high thermal conductive thinner AlN ceramics and upgrade the operation temperature up to 175deg.C.

Analytical Modelling of Dynamic Power Losses Inside Power Modules for 2-Level Inverters
Arne Bieler, Ole Mühlfeld, Danfoss Silicon Power, D
Simplified power loss calculation models are commonly based on linear scaling of losses from datasheets, which reduces their accuracy, and do not allow dynamic load profile investigations in most cases, but stop at steady state considerations of losses and temperature.This paper proposes a modelling approach considering time discrete modelling of load profiles and obtaining electrical input data of chips from more accurately scaled algorithms.

Failure Protection in Power Modules with Auxiliary-Emitter Bond-Wires
Nick Baker, Francesco Iannuzzo, Aalborg University, DK
In this study we show how including an auxiliary-emitter resistor in the design of the power module prevents loss of gate control after device failure, and provides a large warning signal that allows a fault control strategy to be implemented immediately and save the module from explosion.

An Efficient Active Mains Rectifier Bridge Based on Bipolar Technology
Nick Koper, WeEn Semiconductors, NL; John Wood, Silicon Contact, UK
The combination of bipolar technology and an innovative driving method enables the implementation of a cost-effective active mains rectifier bridge. With the new rectifier bridge the power dissipation in the rectification stage of a power converter can be reduced by 70% and the overall system efficiency is increased by up to 1%. In power converters that operate 24/7, the active bridge pays for itself within one year.

Development of New 600V Smart Power Module for Home Appliances Motor Drive Application
Samuell Shin, Bumseung Jin, Kinam Song, Sewoong Oh, Thomas Yim, ON Semiconductor, ROK
This paper presents a new 600V SPM package, which combines with the features of the latest trench Field-Stop technology IGBT and optimized gate driver IC to achieve the excellent solution for motor drives applications in home appliances. Especially, this module is adopted and optimized to integrated bootstrap circuitry in drive IC which can be fully supported for a simple layout and less PCB space to develop a motor drive power stage.

DC-DC Converters

Implementation of an Adaptive Dead Time in Resonant Converters
Christian Oeder, Nikolas Foerster, Thomas Dürbaum, Friedrich-Alexander-University of Erlangen, D
A fixed dead time is not always sufficient in any resonant converter design, neither in every operating point to fully charge/discharge the parasitic half-bridge capacitors. An adaptive dead time represents an alternative and more promising approach. To achieve this, a special control logic is needed, which determines the individual turn-on and turn-off events of the input switches.

Modified Basic DC-DC Converters
Felix Himmelstoss, Karl Edelmoser, Technikum Vienna, AT
Changing the position of the output capacitor in such a way that it connects one input and one output terminal modifies a DC-DC converter. This is here demonstrated with the basic buck, boost, and buck-boost topologies. The changes concern the input buffer capacitor C1, caused by a modified input

current form and the necessary voltage across the capacitor C2. The dimensioning of the converter is compared. Small signal models and transfer functions are derived and measurements of a converter realized with GaN semiconductor devices are shown.

GaN Based Multilevel Intermediate Bus Converter for 48 V Server Applications
David Reusch, Suvankar Biswas, Michael de Rooij, Efficient Power Conversion (EPC), USA
With the power architecture transition from a 12 V to 48 V rack in modern data centers there is an increased interest in improving 48 V power conversion efficiency and power density. In this paper, we explore system optimization of 48 V to 12 V non-isolated, fully regulated, intermediate bus converters (IBC) to maximize efficiency and power density. Two final GaN transistor based experimental prototypes, a traditional buck converter and a three level buck converter are compared.

A FPGA-Based Algorithm for Soft Switched DC-DC Converters with a Variable Transmission Path
Lukas Göbel, Ansgar Ackva, Sebastian Raab, University of Applied Sciences Würzburg-Schweinfurt, D
An approach for control of resonant switching DC-DC Converters is presented. The aim of the control algorithm is to maintain soft switching for a variable transmission path. Second Order Generalized Integrator (SOGI) and a Frequency Locked Loop [1] are used for frequency detection. The primary current of the transmission path is the input signal of the SOGI. With the filtered outputs v' & qv' the angle is calculated and the switching time is determined by compensation of propagation delays [2].

Compact Bidirectional GaN Buck-Boost Converter for Negative Rail Supply in Bipolar DC-Grids
Sebastian Klötzer, Sebastian Fahlbusch, Ulf Müter, Klaus F. Hoffmann, Helmut Schmidt University, D
A volume and weight optimized high-frequency bidirectional buck-boost converter for negative rail supply up to -300 V is presented. By use of state-of-the-art eGaN-HEMTs, switching frequencies far beyond the range of similarly rated silicon based converters can be achieved, leading to a significant increase in power density without sacrificing too much of the converter's efficiency. The proposed converter is able to operate in boundary conduction mode at a switching frequency up to 2 MHz.

Exact Analytical Solution of the Peak Gain for the LLC Resonant Converter
Markus Barwig, Christian Oeder, Manfred Albach, Friedrich-Alexander-University of Erlangen, D
The peak gain is a fundamental value for an efficient design of resonant converters. In some cases it is directly given by the maximum of the transferable power, which is likewise the peak of the gain curve. There is a second limit for the maximal usable output power. It's the transition from the ZVS to the ZCS region. This paper gives a survey over the solutions for both limits in CCM and DCM for the lossless converter resulting in a fast and accurate optimization process.

GaN Buck Converter in CCM with Optimized High Frequency Inductors
Sven Bolte, Norbert Fröhleke, Joachim Böcker, University of Paderborn, D
Utilization of wide-bandgap semiconductors such as gallium nitride transistors facilitates the operation at high switching frequencies. Therefore, the volume of filter components like inductors can be reduced which helps to improve the power density of the converter. In continuous conduction mode, the relatively high DC component of the inductor current superimposed by a high frequency component makes high demands in the winding design. Hence, this paper discusses a buck converter with inductors with an alternative, optimized winding concept.

Modelling of a Bi-Directional Converter from a Power Supplying System With Application in Radio Communication Systems
Ivan Nedyalkov, University of Telecommunications and Post, BG; Dimitar Arnaudov, Nikolay Hinov, Technical University of Sofia, BG

In the paperwork a bi-directional converter for power supplying system of radio communication equipment has been reviewed. The converter provides charging of the energy storage elements (ESE)-supercapacitors (SC) and supplying the equipmnet from the SC when needed. The converter is made of a resonant converter and synchronous rectifier. Each one of the bi-directional converters charges a separate ESE from the battery. The developed models allow studying of the system when the converters are working on a common load.

A Bidirectional Quasi-Z-Source Based DC-DC Converter
Yuba Raj Kafle, Graham E. Town, Macquarie University, AU
This paper presents a novel quasi-Z-source based bidirectional DC/DC converter consisting of a quasi-Z-source inverter, high-frequency transformer, and push-pull converter. Both inputs provide buck/boost functionality by incorporating shoot-through states. Operating principles and modulation techniques are presented.

Traction, Ship, Aircraft

Humidity in Traction Converters
Fabian Quast, Andreas Nagel, Siemens, D
In this report we will present a model to calculate the humidity inside railway traction converter cabinets based on the external conditions. With this the humidity related lifetime of IGBT modules can be calculated. The humidity model takes several physical effects into account like humidity absorption in plastic materials, adsorption on walls, condensation and absorption in wicking materials. We will show the correlation of the calculations with experiments.

New Traction Converter with Low Inductive High-Voltage Half Bridge IGBT Module
Bernd Laska, Jan Weigel, Siemens, D; Sven Buchholz, Waleri Brekel, Matthias Wissen, Thomas Gutt, Infineon Technologies, D; Patrick Münster, Till-Mathis Plötz, Hans-Günter Eckel, Robin Schrader, Ingmar Kirchner, University of Rostock, D
Traction systems for Rolling Stock are well suited for an overall system optimization. The innovation objectives are high reliability and availability as well as high energy efficiency, weight reduction and overall cost optimization including operational and maintenance costs. Today?s semiconductor and packaging innovation accompanied with a converter innovation promise significant traction system improvements. The following report will focus on the innovation of the Siemens traction converter platform SIBAC implementing design solutions, which meet recent traction system requirements. The converter platform is based on innovative semiconductors in a new half bridge package. All in all these converter and system innovations promote the attractiveness of public transport.

Nanocrystalline Cores for Common Mode Current Suppression in Electrical Ship Propulsion System - a Case Study
Wulf Günther, Acal BFi Germany, D; Zoran Malbasic, Alewijnse Marine Nijmegen, NL
We introduce an electric ship propulsion system which appeared to be not conformal with EMC requirements for ships after installation. After analysis of electrical, mechanical and dimensional requirements and conditions, we developed oval shaped nanocrystalline cores for common mode suppression, being consistent with mechanical and thermal requirements in this special environment. The article presents the requirements, design of cores, and results in terms of common mode currents.

Discrete 1200V SiC MOSFETs - SMD Package Benefits and Impacts of Multiple Device and Circuit Parameters Mismatch in High Power Parallel Applications
Rajagopalan Jagannathan, Hans-Peter Hoenes, Tushar Duggal, Marco Atzeri, ON Semiconductor, D
The full benefits of SiC technology can be fully realized only when the device structure, package and application circuit parameters are all optimized.Several parameters impact the static, thermal and switching characteristics. This work focuses on the switching benefits of the new 1200V SiC MOSFETs,impact of several device parameters mismatch under parallel operation at high

temperature,impact of gate driver and layout variations, prevention of parasitic (or shoot though) turn-on in bridge applications.

High-Dynamic High-Power E-Motor Emulator for Power Electronic Testing
Sebastian Liebig, Alexander Schmitt, Horst Hammerer, SET Power Systems, D
Inverter testing has become a very important and complex issue during inverter developments. Especially automotive inverters offer multiple functions, high reliability, fault tolerance and must ensure a high level of functional safety. Conventional test methods such as motor test beds or active / passive RL-loads are not suitable to verify inverter functionalities in a sufficient manner. This paper presents a high-dynamic and powerful inverter testing technology: the E-Motor Emulator – testing power electronics without an e-machine.

New Approach of Smart Hybrid Power Module Dedicated to Aircraft Electro-Mechanical Actuators up to 20 kW
Alain Calmels, Julien Richer, Microsemi Power Module Products, F; Shane O'Donnell, Microsemi, IR
This paper presents the work performed by Microsemi within the GENOME project (Optimized Energy Management) on More Electric Aircraft (MEA). The results presented in this paper demonstrate the ability of the Smart Hybrid Power Module to serve the flight controls in commercial aviation.

Diagnostic Technique for Traction Motor Insulation Condition Monitoring by Transient Signal Assessment
Markus Vogelsberger, Martin Bazant, Bombardier Transportation Austria, AT; Clemens Zöller, Hans Ertl, Thomas M. Wolbank, Technical University of Vienna, AT
Nominated for the Best Paper Award
Today's motor insulation in railway traction applications are operating very close to borderline of safe operation. The paper proposes an Online Insulation Monitoring Approach that is able to detect incipient insulation defects - before breakdown by evaluation of the motor current. The paper presents experimental results of a 1.4 MW ASM traction motor for railway applications and investigations on accelerated aging applied on stator slot test fixtures with form-wound coils.

Control, Intelligent Motion

Modelling of Inverter Nonlinear Effects
Simon Wiedemann, Ralph M. Kennel, Technical University of Munich, D; Anton H. Tamas, MACCON, D;
This paper presents a novel modelling technique which makes it possible to represent the overall inverter nonlinear effects by a simple analytical formulation. The proposed model architecture makes it possible to consider various boundary condition in addition to the conventionally used phase current such as the inverter frequency and dc-link voltage which makes it suitable for high performance industrial AC drives.

Self-Commissioning of the Current Control Loop in AC Drives
Simon Wiedemann, Ralph M. Kennel, Technical University of Munich, D
This paper proposes a self-commissioning concept of the current loop of AC machines which consists of three concepts. First, it is shown how the machine inductance and resistance can be estimated by the recursive least square method. Secondly, a novel auto tuning controller is proposed which allows the field engineer to define the system dynamics by specification of the current settling time and overshoot. In order to obtain an exact match witch the specified dynamics, a novel inverter voltage error compensation approach is proposed.

Sensorless Position Estimation for an Externally Excited Synchronous Machine over the Whole Speed Range

Johannes Schuster, Vasken Ketchedjian, Jörg Roth-Stielow, University of Stuttgart, D
This paper presents a sensorless position estimation method over the whole speed for anexternally excited synchronous machine using the rotor current. At standstill and low speeds,the ripple of the rotor current is used as carrier signal to estimate the rotor position. Above acertain minimum speed, the induced voltage is measurable and so the induced voltage isused for the sensorless position estimation method. A switchover strategy between the twomethods is presented.

VSI with Sinusoidal Voltages for an Enhanced Sensorless Control of the Induction Machine
Harith Al-Badrani, Simon Feuersänger, Mario Pacas, University of Siegen, D
The paper deals with a VSI with SiC-switches and an output filter featuring sinusoidal output voltages. It is expected that the range of operation of a sensorless field oriented control scheme can be extended. The high switching frequency allows the design of a small LC output filter. The harmonic content of the machine voltages is minimized. The measured voltages can be used instead of the reconstructed ones for the enhancement of the voltage model and the performance of the control.

Simplified Wide Speed-Range Sensorless Control Scheme for a Permanent Magnet Synchronous Machine
Van Trang Phung, Mario Pacas, University of Siegen, D
This paper deals with a wide speed-range sensorless control for a PMSM, where an enhanced voltage model and a signal injection method are used to drive the machine at low- and high- speed regions, respectively. A combined angle observer is developed to obtain a smooth speed transition between the two speed regions. The main difference to the well-known methods is that the injection method uses a simple algorithm based on a FFT for the extraction of the high-frequency component of the current.

A Stacked 7-Level Common Mode Voltage Eliminated Inverter Scheme with Single DC-link for Open-End Induction Motor Drive
Apurv Kumar Yadav, Kumarukuttan Nair Gopakumar, Krishna Raj Ramachandran Potti, Loganathan Umanand, Indian Institute of Science, IN; Kouki Matsuse, Hisao Kubota, Meiji University, J
This paper proposes a 7-level structure for an open-end induction machine (OEIM) using single DC-link with zero common mode voltage (CMV). The OEIM is fed with inverters from both sides, with each inverter formed by stacking three 2-level inverter and cascading two H-bridges. The inverters are operated such that zero CMV is obtained. No current is drawn from midpoints of DC-link capacitors, thus the neutral point balancing of DC-link capacitor is achieved. The simulation and experimental results are also included to validate the scheme .

Energy Optimal Motion and Rotor Flux Trajectories for an Induction Motor Drive
Gunar Steinborn, Wilfried Hofmann, Technical University of Dresden, D
This paper investigates energy optimal motion and rotor flux trajectories for an induction motor drive, which can greatly reduce loss energy compared to classic time- and energy-optimal motion trajectories at constant rated flux. The influence of constraints for jerk, acceleration and speed on the optimal trajectories is investigated. The reduced effective motor torque, which comes as a side effect of optimization, can be used to downsize the motor for the given task, further reducing loss energy.

Controller Synthesis and Testing in a 48V System Based on Physical Models
Sabin Carpiuc,The MathWorks, GB
In this paper, the controller synthesis and testing in a PMSM-based 48V system is discussed. A state-feedback controller is designed for controlling the currents. The nonlinear model is feedback-linearized using a state and disturbance observer. The PMSM current references in the rotor reference frame are obtained offline using optimization techniques. Then, a model reference adaptive controller for the DC-link voltage is proposed. A dynamic simulator implemented in Simscape Power Systems(tm) is used for testing the proposed solution.

Modeling and Analyzing the Stability of an Induction Motor Drive System using an Output LC Filter
Pascal Combes, Al Kassem Jebai, Schneider Electric, F
Output LC filters are commonly used to filter the high frequency harmonics induced by PWM switching. Their effect is generally disregarded, as non-modeled dynamics are handled by control law robustness. We show that the output filter can easily be modeled and be taken into account in the control design. We provide numeric stability analysis of control laws with or without current feedback. We also prove that it is more favorable tofeedback the drive current than to feedback the motor current.

Synchronization of Multi-Axis Motion Control Over Real-Time Networks
Jens Sorensen, Analog Devices, USA; Christian Aaen, Dara O'Sullivan, Analog Devices, IR
This paper presents novel concepts to synchronize networked motor drives all the way from a network controller and down the motor terminals and sensors. The presented technologies enable much improved synchronization leading to significantly increased control performance.

Lean and Fast Fieldbus based Safety Functionality for Drives in Automation
Jens Onno Krah, Adin Basic, Technical University of Cologne, D
Activating drive internal Safe Torque Off (STO) via safety-fieldbus requires from most product vendors additional safety hardware, e.g. a safety option card. The new approach introduces a new lean and cost efficient technique for a safety-fieldbus based Safe Torque Off (STO). The method is based on standard fieldbuses with black-channel safety communication (PROFIsafe or Safety over EtherCAT) and simple state machines – based on FPGA or ASIC technology – to process the safety protocol.

Renewable Energy and Power Transmission

A Sliding-Mode-Observer for Encoderless Direct Model Predictive Control of PMSGs
Mohamed Abdelrahem, Philipp Catterfeld, Christoph Hackl, Ralph Kennel, Technical University of Munich, D
This paper presents a study of a sensorless control strategy for permanent-magnet synchronous generators (PMSGs) based variable-speed wind turbines (VSWTs). The proposed method is based on a sliding-mode observer (SMO), which estimates the position and speed of the rotor from the back electro-motive force (EMF). To overcome the chattering problem, an adaptive sigmoid function is used. Simulation and experimental results are presented.

Wind Turbine Nacelle Test Bench Using an Optimized Torque Control and an Aerodynamic Real Time Model
Sören Behrens, Johannes Adler, Bernd Orlik, University of Bremen, D; Holger Raffel, Bremen Center of Mechatronics, D; Holger Schlöcker, SIT, D
A wind turbine nacelle test bench was developed. This test bench consists of the complete nacelle of a wind turbine, an optimized torque-controlled TFM drive and a new real-time model of the aerodynamics to realize the same dynamic behavior as at the real plant. In parallel a second wind turbine of the same type was constructed in the open field for later verifications. The benefits of the test bench will be discussed, the design will be explained and the operation presented.

Wind Turbine for Underground Subway Stations
Lilia Galai Dol, Jose Luis Cardassi, Efficacity, F; Alexandre De Bernardinis, IFSTTAR, F
In urban railway stations , the piston effect, caused by the train pushing air, is very pronounced in railway tunnels and is the cause for equipment mechanical stress leading some of them to an over consumption. This effect can be seen like a wind flowand and can be used to generate electricity an add to a microgrid. This solution will be developed and discussed regarding global efficiency,

complexity and control issues. A test bench at reduced scale in laboratory, which emulate the wind turbine system, will be developed.

Assisting passive anti-islanding proposal for Voltage-Controlled Voltage-Source-Inverters
Cristian Chillón-Antón, Marc Llonch-Masachs, Daniel Heredero-Peris, Daniel Montesinos-Miracle, Universitat Politécnica de Catalunya CITCEA-UPC, ES; Marc Pagès-Giménez, Teknocea, ES
This paper exposes the ineffectiveness of passive algorithms when are used in VSIs behaving as a voltage source. And then, proposes a power control error based solution, making evident the islanding detection under non-zero power flow, combined with monitoring the micro-grid area to avoid zero power flow situations that make islanding detection unfeasible.

Evaluation of DC-to-DC-Converter Impedance Passivity Using Pseudo-Random Test Signals
Leopold Ott, Yunchao Han, Bernd Wunder, Fraunhofer Institute IISB, D; Martin März, University Erlangen-Nuremberg,D; Fabian Bodensteiner, Blacbird Technologies, D
A detailled design procedure for droop controlled power sources in low-voltage DC micro grids yielding optimized dynamic performance and system-level stability is outlined. The basic approach is broadened to cover various source converter types taking specific effects like the right half plane zero in boost-type converters into account. To verify the design procedure, a frequency domain measurement approach using pseudo-random test signals is described and used on exemplary converter systems.

Solving Isolation- and Power Supply Problems for Current Monitoring in High Voltage Power Line Application
Bernhard Strzalkowski, Analog Devices, D; Kelven Mo, Analog Devices, CN
Power transmission systems have evolved into vast interconnected power delivery networks that link multiple generators and loads. The system must monitor individual branches of the grid and quickly locate fault condition for quickly recovering operation. Fault indicator system is composed of functional blocks: energy harvesting, power management, processor, analog front-end and com-munication interfaces. The most important requirements are high reliability, fast communication interface, efficient energy harvesting, low power consumption.

Zero Vector Placement Strategies in Space Vector Modulation of Inverters for UPS Applications
Lorenzo Giuntini, GE Consumer & Industrial, CH
Space Vector Modulation is a popular technique for driving power converters. Alternative switching sequences may optimize power losses and affect harmonic content.When SVM is used in UPS applications, power losses are of particular interest, as most UPS installations are energy-intensive. This paper reviews alternative switching strategies for UPS inverters, evaluating power losses and side effects. The analysis is supported by experimental measurements on high power double-conversion UPS.

Passive Components, Sensors, Diagnostics

Advanced Solutions in Over-Current Protection of Hvdc Circuit of Battery Powered Electric Vehicle
Mitja Koprivsek, ETI Elektroelement, SI
This paper shows the new approach for protection of electric energy storage batteries in order to prevent heavy damage in case of sever electrical fault, e.g. direct short circuit on the battery. Existing solutions with Pyroswitches with parallel Fuses has disadvantages. Proposed paper presents battery over-current protection system with specially designed Pyroswitch and melting Fuse in parallel. This connection can be triggered externally, is able to cover all time-current circumstances and will discharge the DC-link capacitor.

Inductive Power Transfer Systems for Rotating Applications
Nikolay Madzharov, Raycho Ilarionov, Valeri Petkov, Lyudmil Petkov, Technical University - Gabrovo, BG
In a number of innovative technologies the transfer of electrical energy to rapidly rotating objects plays an important role. This article revises the RIPT constructions and requirements, defined by the speed of rotation, along with the design methodology, mechanical and electromagnetic analysis. Also it introduces the methodology for electrical design and gives a detailed description of simulated electromagnetic processes.

Coupled-Inductors Losses Modelling for Size and Weight Optimization Process Avoiding Time-Consuming Co-Simulations
Leyla Arioua, Menouar Ameziani, VEDECOM, F
The multiphase interleaved power converters with coupled inductors enables us to reduce the size of inductors and increase high power density comparing to non-coupled inductors topologies. Hence, estimation models for core and copper losses in the coupled inductors are required to take advantage of coupling and optimize inductors size when minimizing total losses. This paper deals with a four-phases interleaved coupled Boost converter based on SiC
MOSFET for Electric Vehicle (EV) powertrain application. In order to estimate copper loss, an approximation model of equivalent AC resistance is proposed, which allows to avoid timeconsuming co-simulations. Concerning the core loss, a comparison between the well-known Steinmetz approach, the Improved Generalized Steinmetz Equation and the loss obtained using the 3D transient Finite Element calculations is conducted to find the most appropriate for the optimization process.

Enlarging the Standard Permeability Set of Powder E-Cores by Combination of Different Perm Core-Halves
Paul Winkler, Wulf Günther, Acal BFi Germany, D
Sendust E-cores are available in standardized sizes and permeabilities. These cores can be combined to get a set of new perms without inserting any air gap or the creation of new materials. We show the new permeability levels derived by combination and the calculation of a mixed-core-choke. The saturation behaviour of a mixed core including tolerance effects is compared to the one of the cores it is composed of. On one mixed core example we explain the H-field distribution in the two different core halves, derived by Finite Element analyses.

Guideline for Hysteresis Curve Measurements with Arbitrary Excitation: Pitfalls to Avoid and Practices to Follow
Erika Stenglein, Daniel Kübrich, Manfred Albach, Thomas Dürbaum, Friedrich-Alexander-University of Erlangen, D
The voltamperometric method is used to measure hysteresis curves due its apparent simplicity. However, distortions caused by the digital oscilloscope are often disregarded. In this paper, the influence of the data acquisition system on the measured shape of hysteresis curves and its impact on core losses are discussed separately. In addition, some pitfalls of this method are analysed and recommendations for the measurement are given. The aim of this paper is to provide a guide for an easy reproduction of the measurement setup in any laboratory.

Comparing Inductive Components for Different Boost Converter Topologies in a PV System
Michael Schmidhuber, Christian Reichhart, SUMIDA Components & Modules, D; Marco Jung, Fabian Schnabel, Fraunhofer IEE, D
This paper presents a comparison study of new inductive components for different boost converter topologies in a photovoltaic (PV) system. To increase the power density of the system new Silicon Carbide (SiC) semiconductors for faster switching as well as new inductive components were used. The increased switching frequency leads to a reduction in volume and material, but increases the thermal resistance of the inductive device, too. The design and the analysis were verified in a 30 A PV boost converter demonstrator.

Linear Machine with a Magnetic-Coupled Structure Based on the Transverse Flux Technology
Jannik Ulbrich, Alexander Norbach, Bernd Orlik, Holger Raffel, University of Bremen, D
Linear applications are important for various transport and processing applications. In this paper a new concept for a linear drive is introduced designed under the premise of compactness and material efficiency. In general, the idea of transverse flux machines is used, but the important difference is the magnetic coupling of the strands.

Wide Bandwidth Current Sensor Combining a Coreless Current Transformer and TMR Sensors
Nathan Tröster, Johannes Ruthardt, Maximilian Nitzsche, Jörg Roth-Stielow, University of Stuttgart, D
This paper presents a current sensor to measure commutation currents in power electroniccircuits. The current sensor consists of a coaxial housing, to achieve a low insertioninductance, which has to be placed into the current carrying conductor.

Precise Voltage Measurement for Power Electronics with High Switching Frequencies
Maximilian Nitzsche, Matthias Zehelein, Nathan Tröster, Jörg Roth-Stielow, University of Stuttgart, D
This paper compares different approaches in precise measurement of gate voltages as well as drain-source voltages of modern SiC and GaN MOSFETs. An approach to calculating the necessary bandwidth of a voltage probe to reproduce the voltage slope is presented. Furthermore, state-of-the-art voltage probes are compared in means of bandwidth, common-mode reduction and response on EMI.

Fault Diagnosis in Frequency Inverter with Space Vector Recognition of Output Voltage
Rudolf Mecke, Harz University of Applied Sciences, D
In case of non-proper operation of inverter the space vector of output voltage differs from the circle or hexagon. Space vectors for different failure types (short-circuit, non switching of an IGBT, unsymmetrical phases) can be simulated and saved. By comparison with the measured space vector the failure can be located fast and precisely. This automatic pattern recognition can be used for two-level and especially for three-level inverters and saves time for the frequency inverter manufacturer.

Characterization Platform for Modular Power Converters
André Andreta, Yves Lembeye, Jean-Christophe Crébier, Alexis Derbey, University Grenoble Alpes - G2Elab, F; Luiz Fernando Lavado Villa, Univ. Paul Sabatier, LAAS-CNRS, F
This paper presents a test bench developed to characterize modular power converters and Power Electronics Building Blocks (PEBB) converters. It is composed by a thermally isolated device where the temperature and the air flow are measured and can be regulated. A device under test is placed inside and all the important signals are acquired and processed. Large and multi-dimension experimental plans can be automated thanks to computer interface in order to sketch converter abacus and characteristics.

Rare-Earth Free EV and HEV Motor Drives: State of the Art
David Cabezuelo, Edorta Ibarra, Estefania Planas, Iñigo Kortabarria, Jose Ignacio Garate, University of the Basque Country (UPV/EHU), ES
Permanent Magnet Synchronous Machines are widely used in the electric vehicle market. Considering rare-earth market concerns, manufacturers and academia are working on alternative motor drives based on Induction, Synchronous Reluctance and Switched Reluctance technologies. Being efficiency and power density the key aspects of machines with reduced or no magnets, this paper will focus on recent advances on rare earth free machine designs for improved power density.

High Power IGBT Devices

A 6.5kV 1000A IGBT Module with Side Gate HiGT

Hiroyuki Koguchi, Taiga Arai, Takayuki Kushima, Tatsuya Matsumoto, Hiroki Kawano, Takahiro Saiki, Tetsuo Oda, Hitachi Power Semiconductor Device, J; Masaki Shiraishi, Hitachi, J
Nominated for the Young Engineer Award
New 6.5kV 1000A IGBT module was developed. A side-gate HiGT (High Conductivity IGBT), which has small Cres and fine pattern cell, is applied to this module. It realizes that 10% lower Eon+Err and 10% lower Vce(sat) against our conventional planar gate HiGT module. Package concept is same with our 3.3kV and 4.5kV FH version IGBT modules [2]. Thermal resistance Rth(j-c)diode is decreased by 20%, and the internal stray inductance is decreased by 29%. As a result of inverter loss simulation, the output current of the new module can be increased by 33% from the conventional module at 100Hz-1kHz.

Plasma-induced Diode Short-Circuit in Neutral-Point-Clamped Converters
David Hammes, Jan Fuhrmann, Robin Schrader, Sidney Gierschner, Hans-Günter Eckel, University of Rostock, D; Dietmar Krug, Siemens, D
Nominated for the Best Paper Award
Nominated for the Young Engineer Award
Some HV-IGBTs or diodes in a Neutral-Point-Clamped (NPC) converter can be switched off without taking blocking voltage. Therefore, plasma remains inside these semiconductors and will be removed via charge carrier recombination, taking over blocking voltage or a short-circuit event. The last one is yet described for the IGBT, but not for the diode. The presented investigations within this paper examine the origin, the possible influences and failure cases of this new kind of short circuit.

The third generation 6.5kV HiPak2 module rated 1000A and 150°C
Charalampos Papadopoulos, Boni Boksteen, Maxi Andenna, Elizabeth Buitrago, Samuel Hartmann, Sven Matthias, Chiara Corvasce, Arnost Kopta, Umamaheswara Vemulapati, Gontran Pâques, Raffael Schnell, Friedhelm Bauer, Daniel Prindle, Marco Bellini, Munaf Rahim
This paper includes the improvement of 6.5kV IGBT and Diode chipset for 150°C operation and increase of current capability in inverter and rectifier mode.
The focus of the paper is to show how thin increase in temperature and current could be achieved and in the end finalized with full module dataset of the final design.

Design and Development of an Integrated Power Module Used in Low Voltage DC/AC Hybrid Circuit Breaker
Kenan Askan, Michael Bartonek, Eaton Industries, AT; Klaus Sobe, Infineon Technologies, AT
This paper reports on the design and development work of an integrated power module (IPM) used in an Hybrid Circuit Breaker (HCB) application. Two previously characterized power insulated-gate bipolar transistors (IGBTs) and silicon diode bare dies, together with control electronics, are placed on both sides of an Al2O3 substrate. This allows the smallest footprint with the highest current density, and the fastest current commutation to be integrated into a standard miniature circuit breaker (MCB) housing. An experimental setup is developed to analyze the surge current capability of the technology and to design the most appropriate technology with the highest reliability and most compact power module.

New 1200 V IGBT and Diode Technology with Improved Controllability for Superior Performance in Drives Application
Christian R. Müller, Alexander Philippou, Christian Jäger, Max Seifert, Infineon Technologies, D; Antonio Vellei, Michael Fugger, Infineon Technologies, AT
1200 V IGBT and diode technology optimized for drives application are presented. The IGBT structure is based on micro-pattern trenches with sub-micron mesas which provide strongly reduced static losses and offer a high level of controllability. For the diode, an improved performance with significantly reduced oscillatory behavior is achieved. In power modules, higher current density and larger output currents are reached due to the superior performance of IGBT and diode.

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Converter Design and Integration

Fully Optimized Discrete Coupled Inductor DC/DC Converter as The TriMagiC converter
Mitsunao Fujimoto, Yutaka Naito, ALPS Electric, J
Took deep analysis of coupled inductor system in terms of delta flux density (Bm) to each part (Lk and Lm) separetly. and adopted optimal magnetic material to each part (LiqualloyTM to Lk, Ferrite to Lm) and designed Transformer based on Bm setting. Then could obtain approximately 30% less magnetics size and keep high level converting efficiency.

Ultra Compact 2kW 12V-48V Converter Using a 4-Phase Coupled Inductor
Patrick Deck, Christian Peter Dick, Institute for Automation Engineering/TH Köln, D
This paper presents the design and experimental validation of a 4-phase interleaved mode 2kW 12V-48Vbidirectional bordnet converter using a 4-phase coupled inductor consisting of low-µ nano-crystalline metaltape. In a first step the design of this inductor and an analytic volume comparison to standard 4-phaseinterleaved mode converters is presented. The design will be based on rho/phi-pareto analysis optimizingthe design process. Finally the paper concludes in the experimental validation of the converter.

Thermal Analysis of a Directly Liquid Cooled Silicon Carbide Resonant Inverter for High Voltage Generation
Ulf Müter, Klaus F. Hoffmann, Helmut Schmidt University of the Federal Armed Forces Hamburg, D; Oliver Woywode, Jens Radvan, Philips Medical Systems DMC, D
One approach to reduce volume and weight of high voltage generators used in industrial ormedical applications is the higher integration of the power inverter into the high voltage tank. Therefore, this paper presents investigations concerning the thermal behaviour of a directly liquid cooled silicon carbide resonant inverter for high voltage generation. The designed full-bridge resonant converter based on silicon carbide semiconductors operates at frequencies above 500 kHz and a maximum output power of 80 kW.

Highly Integrated Two-Phase SiC Boost Converter with 3D Printed Fluid Coolers and 3D Printed Inductor Bobbins
Arne Hendrik Wienhausen, Alexander Sewergin, Rik W. de Doncker, RWTH Aachen University, D
Nominated for the Best Paper Award
Nominated for the Young Engineer Award
With the use of Selective Laser Melting (SLM) new 3D printed cooling structures for power converters can be realized. In this paper, a highly integrated two-phase interleaved bidirectional boost converter using discrete SiC-MOSFETs and 3D printed fluid coolers as well as 3D printed inductor bobbins is presented. The converter is operated at a high switching frequency of 400 kHz and features a high power density of 32.6 kW/dm3 while delivering 15 kW of output power.

High Step-Up High-Frequency Zero-Voltage Switched GaN-Based Single-Stage Isolated DC-DC Converter for PV Integration and Future DC Grids
Armin Jafari, Elison Matioli, POWERlab, EPFL, CH
In this work, a high step-up single-stage DC-DC micro-converter for photovoltaic (PV) applications is demonstrated. To reduce the size of passive components and the overall system, the circuit was designed to work at a high switching frequency of 300 kHz, using GaN power HEMTs. For the high step-up ratio required in this application, we designed a high-frequency high step-up planar transformer, which enabled a high boost of voltage, in just a single-stage DC-DC converter, reaching an efficiency of 93%.

Control in Power Electronics

Control Scheme for Wide-Bandgap Motor Inverters with an Observer-Based Active Damped Sine Wave Filter
Franz Maislinger, Hans Ertl, Technical University of Vienna, AT; Goran Stojcic, Florian Holzner, Christoph Lagler, B&R Industrial Automation, AT
Nominated for the Young Engineer Award
A method for active damping of a two-stage sine wave filter for wide-bandgap motor inverters is presented avoiding any sensing of filter voltage/currents. The method is based on a linear observer model, which is used for estimating the capacitor filter currents required for implementing the active damping. The inverter's motor currents are controlled using a conventional PI-type controller with feedback of the estimated capacitor filter currents. Using the proposed method, no additional measurements and dissipative damping losses appear.

Adaptive Frequency Control of DC-DC-Converters for Maximum Efficiency Using Artificial Neural Network
Lukas Keuck, Arsalan Munir, Frank Schafmeister, Joachim Böcker, University of Paderborn, D
It is common practice to operate DC-DC converters at one constant switching frequency. However, the loss-optimal switching frequency depends on the operation point. The loss-optimal switching frequency depends on various parameters so a look-up-table suffers from huge data volume. To overcome this problem, an artificial neural network is trained. The artificial neural network is embedded in an adaptive high-dynamic control. Experimental results show an efficiency improvement of approximately 1%.

AC Input Current Distortions and Compensation Schemes of PFC Stages Working in Critical Conduction Mode
Markus Schmid, Infineon Technologies, D
Active PFC stages are often driven in Critical Conduction Mode with valley switching and frequency limitation. This control method implicates AC current distortions especially with lower power level or higher AC input voltage. The paper illustrates the mechanisms resulting in these distortions and proposes compensation methods implemented with help of a digital controller. Furthermore, the influence of the EMI filter capacitor on the input current is examined. A compensation method is proposed

Adaptive and Robust Stabilization of Flyback Power Converters with Digital Control
Gaetan Beneux, Louis Grimaud, Safran, F; Pierre Riedinger, Jamal Daafouz, SAFRAN-CRAN, F
DC/DC converters are electrical systems used to adapt an input source to an output load. We propose a switched and adaptive control strategy with global asymptotic stability guarantees. The hybrid nature of these dynamical systems is taken into account through a switched system modeling. Input source and output load bounded variations are handled using a parameter estimation procedure. This paper shows a physical real time implementation of the control algorithm using C2000-familly processor from Texas Instrument.

Asymmetric Current Control of Grid Connected 3-Phase Cascaded H-Bridge Multilevel Inverter
Taha Lahlou, Markus Herzog, Nagendra Ningappa Badiger, Hans-Georg Herzog, Technical University of Munich, D
In this paper, a flexible current control scheme is proposed based on symmetrical component extraction, for the control of multilevel inverter in grid connected battery storage applications. To drive and compensate the unbalanced currents in grid tie operation, proposed method provides more flexibility as compared to classic vector oriented current control by means of injecting or extracting unequal magnitudes current in each phase. Unbalanced line currents are decomposed into their symmetrical sequence components. Filter based extracted positive, negative and zero sequence components are controlled separately by means of PI controller in rotating dq-reference frame. The control method is simulated in Matlab/Simulink and simulation results are validated on hardware test bench set up.

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Gate Driver

IGBT Power Stage Delay Calibration is Minimizing Current Imbalance in Large Power Modules with Isolated Multiply Segmented Paralleled Half Bridges
Sven Teuber, Marco Honsberg, Günter Katzenberger, Axel Kubitz, SEMIKRON Elektronik, D
The paper comprises an overview about the utilized IGBT driver methods to drive multiply paralleled power stages like IGBT modules. Typical drawbacks of the approaches found in practice and the logical conclusion to propose a totally delay matched and low jitter configuration that allows clustering of up to 12 individual power blades by individually digitally tuned gate drivers. The measurement of existing standard solutions and the results of the described totally matched approach is shown and the corresponding topologies and experimental switching test results are presented in this paper.

Performance Comparison Between Voltage Source and Current Source Gate Drive Systems
Wolfgang Frank, Infineon Technologies, D; Ziqing Zheng, Infineon Technologies, CN
This paper presents the comparison of two gate driver boards, which are operated with the same power module. One solution is realized using a gate current control driver IC, while the other solution uses a conventional gate driver IC with external buffer. The power module is a 1200 A / 1200 V module designed for high power applications. The functionality of both boards is analysed and the switching performance is compared.

High-Side Driver Supply With Reduced Coupling Capacitance
Jens Friebe, Leibniz Universität Hannover, D; Oliver Prior, SMA Solar Technology, D; Marcin Kacki, SMA Magnetics, PL
The capacitive coupling of high-side driver circuits is in the range of the output capacitance of new semiconductors. To reduce the negative impact of the capacitive coupling, in particular common mode currents into the heatsink, a new gate drive supply circuitry is presented, discussed and verified with laboratory measurements. Moreover, the impact on the inductor design is being discussed, including a description of further optimization potentials.

An Isolated Voltage-Source Integrated SiC Gate Driver IC with a Slew Rate Adjusting for Gate-Resistance-Free
Yasufumi Kawai, Yoshiharu Anda, Shuichi Nagai, Tsuguyasu Hatsuda, Noboru Negoro, Shingo Enomoto, Osamu Tabata, Songbaek Choe, Panasonic, J
This work presents a novel galvanic isolated gate driver IC, which drives a SiC power device by itself without any isolated voltage source, buffer ICs and gate resistances due to its internal wireless signal power transmission and slew rate adjusting function. The fabricated compact gate driver with a 5 V power supply successfully drives a 120 A SiC power device stably up to 30 kHz. This demonstrates a new technique to drive a SiC power device without negative gate bias at off-state by eliminating the gate inductance.

A Gate Driver Approach using Inductive Feedback to Decrease the Turn-on Losses of Power Transistors
Michael Ebli, Martin Pfost, Technical University of Dortmund, D
A novel gate driver approach for power transistors is introduced, allowing to decrease the turn-on losses of power transistors. The decrease in turn-on switching losses is possible through a transformer, which couples energy from the power current path to the control current path.Measurements of a 650V silicon superjunction MOSFET show a turn-on energy reduction of up to 30 %.

Passive Components

Design and Optimization Method of PCB-Integrated Inductors for High-Frequency Converters

Ammar Chafi, Nadir Idir, Arnaud Videt, Thierry Duquesne, University of Lille - L2EP, F; Hassan Maher, LN2, Université de Sherbrooke, CA
Power electronics converters require energy storage components. The DC-DC converters need themagnetic storage components which take a large volume. The new power GaN transistors allow toincrease the operating frequency of the power converter. The consequence is a reduction of the valuesand the dimensions of the passive components mainly the inductors. In this paper, a design methodfor PCB-integrated inductors is proposed. It is based on the optimization approach of inductors volume.

Simulating the Parasitic Capacitance of Inductive Components
Stefan Schefler, Jörn Schliewe, Stefan Weber, EPCOS, D
A simulation based method for calculating the parasitic capacitance of inductive devices is presented. The method allows the consideration of the influence of the magnetic material which is very important for practical applications. Additionally, different winding techniques can be taken into account in the calculations. We show with an example how the winding technique affects the overall parasitic capacitance.

Future Winding for Next Power Electronic Generation
Dennis Kampen, BLOCK Transformatoren-Elektronik, D
In this paper a new winding technique is presented. The new design offers significant advantages in life time, losses, potential control, cooling, current density and cost.

Ripple Current Determination for Inductors in a DC/DC Converter Both With and Without Magnetic Bias
Tobias Appel, Daniel Benner, STS Spezial-Transformatoren Stockach, D
A study of inductor models applicable in a DC/DC converter is presented. The main focusis to determine the optimum ripple current with respect to given boundary conditions e.g. asaturation flux density with and without magnetic bias. It becomes clear that different fluxdensities require different ripple current determination. It is a guideline for determination optimalripple currents for different inductor designs.

Development of Accelerated Testing of Thermal Degradation in Metallized Ceramic Substrates for SiC Power Modules
Hiroyuki Miyazaki, Hideki Hyuga, Hiroshi Sato, Hiroshi Yamaguchi, Kiyoshi Hirao, National Institute of Advanced Industrial Science and Technology (AIST), J; Shoji Iwakiri, Hideki Hirotsuru, Denka, J
In order to shorten the testing time of thermal cycling for metallized ceramic substrates, a new accelerated fatigue test was developed. Maximum tensile stress in the ceramics during thermal cycle was estimated by FEM analysis. The stress swing in the ceramic substrates during the thermal cycling was simulated by 4-point bending the test piece repeatedly at a constant temperature. The time to failure by repeated loading for some ceramic substrates was about 1/100 of the time to delamination of the copper plate by the thermal cycling.

SiC Devices II

Beyond the Datasheet: Commercialization of 700 V - 1.7 kV SiC Devices with Exceptional Ruggedness for Automotive & Industrial Applications
Avinash S. Kashyap, Amaury Gendron-Hansen, Dumitru Sdrulla, Bruce Odekirk, Dennis Meyer, William Brower, Changsoo Hong, Microsemi, USA
This paper will discuss (a) Microsemi's approach to create widespread adoption of SiC devices via rapid commercialization, and (b) key ruggedness metrics based on industry feedback that is not commonly presented in either datasheets or qual standards, but can potentially unearth underlying device and package weaknesses undermining reliable long-term operation.

6.5-kV Full-SiC Power Module (HV100) with SBD-embedded SiC-MOSFETs
Jun-ichi Nakashima, Akinori Nishizawa, Tetsu Negishi, Shin-ichi Iura, Akihisa Fukumoto, Yoshiko Obiraki, Takeshi Oi, Yohei Mitsui, Hiroshi Nakatake, Yoshihiko Toyoda, Koutarou Kawahara, Shiro Hino, Hiroshi Watanabe, Mitsubishi Electric, J
Mitsubishi Electric has developed 6.5 kV Full SiC power module with HV100 standardized package and all mounted devices are SiC devices. These devices are the SBD-embedded SiC-MOSFETs. Embedding SBDs within the SiC-MOSFET can suppress bipolar degradation and reduce recovery current of the body diode in the MOSFET. In addition, we optimized an internal structure of the HV100 package, and achieved stable electrical characteristics.

Is an Antiparallel SiC-Schottky Diode Necessary? Calorimetric Analysis of SiC-MOSFETs Switching Behavior
Otto Kreutzer, Markus Billmann, Fraunhofer Institute IISB, D; Martin März, FAU Erlangen-Nuremberg, D
Within this paper the switching losses of a Wolfspeed 25mOhm bare die SiC-MOSFET are measured in a hard switching 800 V DCDC-converter with five different commutation partners. A small and a large SiC Schottky diode, an SiC-MOSFET body diode and a combination of body and Schottky diode are compared at different switching speeds and switching currents. The results show quite well the reverse recovery charge dependence of SiC-MOSFET?s body diode on switching speed.

High Power IGBT System Applications

A Test Bench for Thermal Characterization of IGBT Power Modules Over Mission Profiles
Christoph van der Broeck, Rik W. de Doncker, RWTH Aachen, D; Hao Zeng, Robert D. Lorenz, University of Wisconsin-Madison WEMPEC, USA
For thermal stress validation and lifetime estimation of power electronic modules data obtained during realistic operation is crucial. For this reason, the thermal characterization of IGBT power modules over mission profiles is discussed in this paper. A test bench is introduced, which allows to apply realistic loads to an IGBT power module, which occur for example during a mission profile of an electric vehicle.

Floating Gate Method to Protect IGBT Module from Explosion in Traction Converters
Enea Bianda, Vinoth Kumar Sundaramoorthy, Gerold Knapp, Alexander Heinemann, ABB Switzerland, CH
A method using floating gate is suggested to avoid explosion of IGBT modules in converters by redirecting the fault current through good chips in the module and reducing the current concentration in the faulty chip. The proposed method was able to avoid explosion of various tested IGBT modules at a short circuit energy of 7.2 kJ and/or 16.2 kJ in a test set up.

A Condition Monitoring System for Power Semiconductors in Wind Energy Plants
Wilfried Holzke, Holger Groke, Alexander Brunko, Nando Kaminski, Bernd Orlik, University of Bremen, D
With the increase of renewable energy power plants, the amount of power converters increases also. Changes in temperature and humidity due to operation and environmental conditions result in a degradation of the semiconductors. Currently data is collected in an active, commercial wind farm to find events and conditions which have a major impact on the degradation. For the longtime recording a flexible measurment system was build. Now the measurment system will be extended by an online monitoring system based on a lifetime prediction model.

Advanced Packaging Technologies II

Sintering Cu Bonding Paste: Cycle Reliability and Applications

Hideo Nakako, Yoshinori Ejiri, Chie Sugama, Yuki Kawana, Motohiro Negishi, Yuichi Yanaka, Dai Ishikawa, Hitachi Chemical, J
New high reliable die-bonding material has been highly demanded cause of the high temperature operating power device. Our sintering Cu bonded layer have superior bonding reliability than those with high lead solder bonding layers as compered by thermal cycle test and power cycle test. This sintering copper paste curable at temperature of over 225 °C in H2 atmosphere under pressure-less condition. Therefore, it can apply to Cu wire connection and Cu clip connection that are alternative to Al wiring.

Selective Silver Sintering of Semiconductor Dies on PCB
Fabian Dresel, Sigrid Zischler, Sebastian Letz, Andreas Schletz, Fraunhofer Institute IISB, D; Michael Novak, Continental, D
Organic printed circuit boards (PCB) together with standard joining technologies offer a cheap solution for signal and power electronics. These joining technologies reach their limit for high temperatures. This work proposes selective silver sintering as a new joining technology for the mounting of bare die semiconductors directly onto the PCB for high temperature applications. To prove the feasibility a lifetime and reliability test is carried out on prototypes.

Feasibility of Copper-Based Ribbon Bonding as an Assembly Method for Advanced Power Modules
Stefan Behrendt, Ronald Eisele, Katja Andersen, University of Applied Sciences Kiel D; Tao Xu, Christoph Luechinger, Kulicke & Soffa Industries, USA; Martin Becker, Andre Bastos Abibe, Robert Woehl, David Benning, Frank Osterwald, Danfoss Silicon Power, D
This investigation compares IGBT assemblies interconnected with aluminum-copper and bare copper ribbons to assemblies built with standard methods as benchmark. Assemblies with silver sinter die attach and optimized ribbon bonding were submitted to short power cycles for reliability testing. Reduced coefficient of thermal expansion mismatch and stronger interfaces with these interconnections show improved reliability compared to the benchmark. The new technologies are a promising alternative for advanced power modules.

HVDC Transmission Systems

Design of a Surge Arrester Based Load Commutation Switch for Hybrid HVDC Breakers and MVDC Breakers
David Weiss, Mathias Duerr, Noemi Drack, Felix Kirchhoff, Philippe Maibach, ABB Switzerland, CH; Arman Hassanoor, ABB China, CN
In this paper, the switching behavior of a combination of series and parallel connected IGBTs with a parallel surge arrester is investigated. The focus is on the application of an auxiliary power electronic switch, referred to as a load commutation switch, for the hybrid HVDC breaker. The switching behavior of a state of the art SPT+ IGBT is compared to the switching behavior of the Bi-Mode Insulated Gate Transistor. In addition to that, design aspects of the LCS are discussed.

Fault Discrimination in Bipolar HVDC MTS Equipped with Bus Bar Breakers
Max Görtz, Rene Sander, Simon Wenig, Wolf Schulze, Michael Suriyah, Thomas Leibfried, Karlsruhe Institute of Technology (KIT), D
A system-wide valid HVDC MTS protection scheme has been developed for converter and dc-side Circuit Breaker action control. Furthermore, a beneficial earthing scheme for bipolar MTS is presented.

An HVDC Current Flow Controller for Multi-Terminal Grids
Viktor Hofmann, Mark-M. Bakran, University of Bayreuth, D
This paper proposes a modular and scalable current flow controller (CFC) for meshed High Voltage Direct Current (HVDC) grids. The exchange of active power is performed directly between two DC branches and the circuit can be directly installed at a DC node without any additional AC grid. The

CFC is especially suitable for medium CFC voltage ratings. Furthermore, a comparison of different CFCs is performed which all allow an interline power exchange but are designed for different CFC voltage ratings.

Software Tools and Applications

S-parameter Based Simulation Modeling a Power Module Independent of Measurement Data
Junichi Kashiwagi, Hiroyuki Sakairi, Naotaka Kuroda, Hirotaka Otake, Ken Nakahara, ROHM, J
The authors present an S-parameter based simulation model of a power module (PM) including SiC transistors to predict how the PM operates. Electromagnetic (EM) simulation creates the S-parameter component to represent the EM response of the PM except for the semiconductor dies therein. We finally combine this PM model with the die model of the transistor to build the simulation model of the whole PM. This modeling process depends on no measurement data, but the combined model finely predicts the experimental waveforms in a switching circuit.

Electro-Thermal Simulation for Predicting the Temperature of SiC Dies in the Power Module of a High Frequency Operating Power Converter
Yohei Nakamura, Hirotaka Otake, Yusuke Nakakohara, Hiroyuki Sakairi, Naotaka Kuroda, Ken Nakahara, ROHM, J; Tristan M. Evans, University of Arkansas, USA
The accurate electro-thermal simulation was performed by using an SiC die model to predict the temperature of SiC metal-oxide-semiconductor field-effect transistor (MOSFET) dies. This model incorporates a body diode characteristic which is dependent on the gate-voltage. Therefore, it yields a precise power loss estimate for a buck converter with a 1200 V, 40 A SiC module operating at a switching frequency of 50–350 kHz. The deviation between the measured and simulated results, even for the worst case, is less than 6.0%.

Comparison of Dynamic Performance of a Lab-Scale Modular Multilevel Converter and its Equivalent Model for Real-Time Simulation
Nikola Stankovic, Opal-RT Europe, F; Jerome Rivest,Wei Li, Jean Belanger, Opal-RT Technologies, CA
Comparison of dynamic performance of a lab-scale modular multilevel converter and a corresponding mathematical model for real-time simulation is presented. Energy distribution inside the converter's arms is regulated by using an optimization-based algorithm for generating reference difference current. This algorithm can provide high flexibility in setting time constants of the internal dynamics. Comparison of the obtained results is presented and discussed.

Thermal Management

Application of Mmc Alsic Thermocompensators in Power Press Pack Diodes and Thyristors
Alexey Grishanin, Valentin Martynenko, Vyacheslav Eliseev, Mikhail Malygin, Anton Samoylov, Alexander Plotnikov, JSC Electrovipryamitel, RU; Konstantin Nishchev, Mikhail Novopoltsev, Mordovia State University, RU
This paper presents investigation and test results of power press-pack semiconductors with thermocompensators from metal-matrix composite (MMC) AlSiC and brief description of design and manufacturing technology. Our investigations show possibility of AlSiC-TC application in press-pack power semiconductor design. New thyristors with AlSiC-TC and LTJT have surge current capability 30% higher as conventional devices.

Reliability of the Power Module Using the Insulated Substrate with Al/C Composite
Kazuhiko Minami, Shoichiro Wakabayashi, Katsumasa Hirose, Ichiro Ota, Showa Denko, J
In this report, the improvement of reliability is reported by the power module using the insulated substrate with Al/C composite. Aluminum insulated substrate (DAB) with Al/C composite restrain to deform aluminum at heat cycle. From rule of mixtures, Al/C composite of this report is near parallel type. This result is reasonable from Al/C composite structure. In the power module using DAB with

Al/C composite, wrinkle is not formed after heat cycle. As CTE of Al/C composite neared by ceramic, thermal stress is reduced and wrinkle is not formed.

A Development of Resin Insulating Material for High Reliable Enhanced Power Module
Shinji Amanuma, Mitsuo Togawa, Hitachi Chemical, J
The trends of power module are high power density, downsizing and high reliability. To satisfy these requirements, the thermal management of whole package design is vitally important. Especially, we need to consider high heat dissipation, because Junction temp of device will become higher if power will be higher. This paper introduced two types of new products Which to improve above performance well, namely, Resin Insulated High heat dissipation substrate and Hybrid Encapsulation.

Experimental Investigation of Gravity-Driven Two-Phase Cooling for Power Electronics Applications
Devin Pellicone, Advanced Cooling Technologies, USA
Passive cooling approaches are ideal for high reliability systems because they require no moving parts and little maintenance. Some gravity-based two-phase cooling solutions provide a higher performance alternative to current passive cooling solutions. This paper will discuss the recent developments and experimental evaluation of a gravity-driven two-phase cooling solution for medium voltage drive applications.

Integrated Cooling Channels in Direct Bonded Copper Substrate for Silicon Carbide MOSFETs
Alexander Stippich, Maximilian L. J. Battefeld, Rik W. De Doncker, RWTH Aachen, D
A cooling structure etched directly into a direct bonded copper substrate is examined for semiconductor devices including silicon carbide devices. Simulations are carried out for an initial setup and experimentally verified with measurements. Different material combinations are simulated for silicon carbide devices. By integrating a micro-channel structure, a small and efficient cooling system can be achieved.

Thermoelectric Cooling for Bare Dies Power Devices Embedded in PCB Substrates
Shuangfeng Zhang, Eric Laboure, University of Paris, F; Denis Labrousse, Stéphane Lefebvre, ENS Cachan – SATIE, F
In this paper, solutions such as use of thermal vias, thick PCB copper layer and thermoelectric coolers (TECs) will be discussed and compared to optimize the heat dissipation. And the optimum TEC parameters are analyzed to obtain its maximum coefficient of performance (COP). Controlled experiments have been performed to validate the 3D thermal management models and precision calorimetry method will be applied for accurate measurement of power losses in power devices in order to compare thermal performances of the different cooling solutions.

Generic Lumped Parameter Thermal Model with Optimized Use of Computational Resources
Joaquim Pinol Bel, Heinrich Steinhart,University of Applied Sciences Aalen, D
In this paper, a method for efficient computation of generic lumped parameter thermal models is presented. It describes the implementation of thermal model to a given system with a complexity scalable to the available resources. The applied optimization techniques for model computation will be discussed. A performance analysis of the model simulation, regarding the required memory and computing power, will proof that it can be executed in a microcontroller in real-time. A model for an induction machine is presented as an example.

Methodology and More Accurate Electrothermal Model for Fast Simulation of Power HEMTs
Aleš Chvála, Juraj Marek, Luboš Černaj, Patrik Príbytný, Alexander Šatka, Daniel Donoval, Slovak Technical University in Bratislava, SK; Steve Stoffels, Niels Posthuma, Stefaan Decoutere, IMEC, BE
Presented work introduces an advanced methodology for fast 3-D TCAD electrothermal simulation for analysis of power devices. The proposed methodology allows fast simulation of complex systems from

individual semiconductor layers at a frontend up to package and cooling assemblies at a backend. More accurate electrothermal model of power high-electron mobility transistors (HEMTs) is proposed and validated. The influence of the metallization layer geometry on the electrothermal behavior of the multifinger power HEMT is studied.

A New Transient Thermal Impedance Model for Estimating the Dynamic Junction Temperature of IGBT Modules
Xin Ma, Jia Zhao, Yong Yang, Infineon Integrated Circuit (Beijing), CN
The dynamic junction temperature of IGBT module is of vital importance for such as accurate thermal protection and lifetime estimation of power converter system.This paper proposes a new transient thermal impedance model Zth,j_ntc between the junction of IGBT and the built-in NTC thermistor applied to estimate the dynamic junction temperature of IGBT. A case study is also taken as an example to demonstrate the effectiveness of this new model under the system real time operating conditions.

Packaging Technologies

Effect of Lead Frame Structure and Electrical Characteristic Comparison of IPM Module
Samuell Shin, Bumseung Jin, Kangyoon Lee, Jinkyu Choi, Thomas Yim, ON Semiconductor, ROK
This paper will discuss the role and importance of Lead-Frame in PKG as well as solutions that make it easier for designers to reduce wasted energy, lower component count and contribute to a greener world, and characteristics of SPM55 Module.

Development of 140X100 Footprint HV IGBT Module
Daohui Li, Fang Qi, Matthew Packwood, Xiang Li, Yangang Wang, Dynex Semiconductor, GB; Xiaoping Dai, Haihui Luo, Guoyou Liu, Wei Zhou, CRRC Times Electric, CN
New type of 3.3kV/450A half-bridge IGBT module is one of key standardised packages for future high voltage power electronics market. The EM-circuitry simulations have shown a very balance current at switching stage of module operation. The standardised packages can provide lower module level inductance and lower system stray inductance, and fit for common heat sink design for different voltage applications.

Performance Comparison Between Surface-Mount and Embedded Power Modules
Gerald Weis, AT&S Austria Technologie & Systemtechnik, D
A comparison between state-of-the-art surface-mount build-ups and power switches embedded into the printed circuit board shows the high potential of integrated electronics. Measurements at defined operating point(s) verify improved thermal performance due to more heat spreading area, as well as higher achievable switching speed.

PCB-Embedding of Power Dies Using Pressed Metal Foam
Yoann Pascal, Denis Labrousse, Mickaël Petit, Stéphane Lefebvre, François Costa, SATIE, F
This paper presents a new technique to manufacture the top-side contact of a PCB-embedded power die, using a pressed piece of metal foam. The manufacturing process is detailed, simple prototypes are manufactured and electrically characterized, and the technique is used to embed a switching cell. This process is simple and highly cost-effective; the electric resistance of the assembly is close to that of a state-of-the-art industrial package using bond wires and the stray inductance is very low.

Direct Power Board Bonding Technology for 3D Power Module Package
Hidetoshi Ishibashi, Hiroshi Yoshida, Daisuke Murata, Shota Morisaki, Hodaka Rokubuichi, Nobuhiro Asaji, Mitsubishi Electric Corporation, J
Power module is used in a wide range of fields such as, home appliance, industry, railway, automobile, renewal energy etc. Recently, it is increasing to be required further compact, robust, and

energy saving to power modules. This paper introduces the new package technology has the Power board (thicker copper printed circuit board) as inner connection instead of the conventional wire connection. This technology leads further compact, lower package stray inductance, and robustness to answer the market requirements

A Surface-Mountable 1.2 cc Compact Molded Package Suitable for 13 kV SiC MOSFET
Hisato Michikoshi, Hidenori Kitai, Kenji Fukuda, National Institute of Advanced Industrial Science and Technology (AIST), J; Makoto Kanbe, Kazuhiko Omote, Rigaku Corporation,J; Akira Tokuchi, Pulsed Power Japan, J
A surface-mountable 1.2 cc compact package suitable for 13 kV SiC MOSFET was successfully developed for pulsed power applications. To get a compact high-voltage-durable package, the authors applied the transfer molding technologies. The two factors presented were essential. The new package volume is roughly two order smaller than the previous studies'. The package healthily operated up to 18.4 kV peak without discharge, and verified its performance with 13 kV SIC MOSFET.

Particle Prevention During Ultrasonic Welding Process
David Guillon, Samuel Hartmann, Remi Guillemin, Pauline Morin, Fabian Fischer, Dominik Truessel, Harald Beyer, Munaf Rahimo, ABB Switzerland - Semiconductors, CH
Ultrasonic welding has been widely adopted in the Power semiconductor industry for the welding of terminals to metallized ceramic substrate. A primary challenge is to confine/clean the metal particles generated during the welding process.The concept of a particle prevention implemented in our LinPak design will be presented in this paper.

Asymmetrical Flyback Converter in High Density SMPS
Alfredo Medina Garcia, Manfred Schlenk, Infineon Technologies, D; Gerald Deboy, Matthias Joachim Kasper, Infineon Technologies, AT
An 65W USB-PD high density adaptor (20W/cubic inch, cased), based on a single stage asymmetrical PWM flyback topology will be presented, Using MOSFETs, the achieved peak efficiency is close to 95% and the minimum of 93% at full load over input voltage

Reliability Aspects

Reliability Testing of SiC JBS Diodes for Harsh Environment Operation
Thomas Barbieri, Adam Barkley, Edgar Ayerbe, Jonathan Young, Donald Gajewski, Wolfspeed, A Cree Company, USA; Zoltán Major, Vincotech, HU; Matthias Tauer, Vincotech, D
SiC devices are actively being designed into power conversion systems for outdoor applications. Today's system designers seek confidence in the dependability of these devices under high voltage, high humidity operation in these conditions. This work proposes a new test for reliability qualification. Newly released diodes from Wolfspeed, designed with additional environmental resistance, were built into modules and subjected to the new test by Vincotech to independently verify the reliability.

Mechanical Properties and Reliability of Pressureless Sintered Silver Materials for Power Devices
Masafumi Takesue, Tomofumi Watanabe, Keisuke Tanaka, Naoya Nakajima, Bando Chemical Industries, J
This work shows that pressureless sintered silver has a good mechanical performance. The highest tensile strength in this study reached 145 MPa. The value is the best one in previous literature including pressure-assisted sintered silver materials. The broken faces of the sintered silver after tensile tests showed that nano/micro-sized particles were well sintered although it was pressureless sintering.

Control of Partial Discharge with High Temperature Insulating Polymer for High Voltage IGBT Module Application
Muhammad Morshed, Ariful Islam, Thomas Roose, Daniel Longney, Yangang Wang, Andy Dai, Daohui Li, Dynex Semiconductor, GB
In order to ensure the longevity of power module, it is essential to maintain low partial discharge (PD) as it is the key degradation mechanism of encapsulating material in high voltage application. In this work, high temperature polyimides were used in the metallisation edges for impeding the PD. Adhesion promoters, coating thickness and void free coating near the metallisation edged of DBC substrate were considered for improving the PD performance.

Thermal Characteristics Evaluation of Wide Band Gap Power Devices
Shijo Nagao, Katsuaki Suganuma, Tsuyoshi Funaki, Osaka University, J; Kiyoshi Hirao, AIST Chubu, J; Junichi Susaki, Denka, J; Hideki Sato, Japan Fine Ceramic, J
A series of thermal property measurement methods have been examined as the standard evaluation procedures for WBG devices. Three types of thermal measurements are under development. The first one is a measurement of heat conductivity and heat transfer by using a steady-state heat conductivity measurement method. The second is a measurement method by using a mimic device structure with heating element and temperature sensor on a WBG die. The third one is a transient heat transfer evaluation.

From Feasibility to SoP in a 6 Steps Process Described on a SiP Dc-Dc Buck Converter Powermodule
Florian Blum, Dragan Dinulovic, Martin Haug, Michael Brooks, Würth Elektronik, D
The content of this poster is an example of 6 process steps. 1st step starts with the target specification. Continuing with 2nd called feasibility studies. Followed by the 3rd ,design. The 4th step will be first prototyping, followed by 5th, qualification and final test freeze. The 6th and last step is SoP and go to market phase. Several steps in this poster will be supported by analysis- and quality results.

H³TRB Test on 1.2kV SiC MOSFETs
Michael Hanf, Christian Zorn, Nando Kaminski, University of Bremen, D; Martin Domeij, Fredrik Allerstam, Benedetto Buono, Jimmy Franchi, ON Semiconductor, SE; Thomas Neyer, ON Semiconductor, D
We performed H³TRB testing of 1.2kV SiC MOSFETs in TO247 - housing, covered with silicone-gel.

Control and Drive Strategies

Synchronization and Control of Modular AC- and DC-Sided Parallel-Connected Three-Level NPC Inverters
Jochen Staiger, Swen Bosch, Heinrich Steinhart, University of Applied Sciences Aalen, D
This paper describes the synchronization and control of modular three-level NPC inverters, which are connected AC- and DC-sided in parallel. By this, zero-sequence circulating currents are occurring due to several reasons. To avoid circulating currents, a control strategy in combination with a PLL-based synchronization method, which does not require any communication between the inverters, is introduced. Experimental results proof the feasibility of the synchronization method and simulations validate the developed control structure.

Comparison of Two Model based Temperature Control Sysems Implemented on a Three Level T-Type Inverter
Julian Wölfle, Matthias Pitters, Johannes Ruthardt, Johannes Schuster, Martin Stempfle, Jörg Roth-Stielow, University of Stuttgart, D
This paper presents two model based temperature control systems to increase the expectedlifetime of IGBT-power-modules. The increase of the expected lifetime is achieved by increasingthe power losses during low load conditions in order to decrease the junction temperatureswings of the semiconductor

devices in IGBT-power-modules. Each temperaturecontrol system uses two different correcting variables. As correcting variables the currentamplitude and the switching frequency are used.

Real-Time Development Interface Embedded in a Compact Motion Controller
Josef Reill, Cristina Serrano Gonzales, Volker Senft, Martin Pfau, DLR- German Aerospace Center, D
A real-time interface for motor control development embedded in a single PCB is presented. The CPU is supporting EtherCAT communication and computes the control algorithm that can be implemented with Matlab/Simulink toolchain. The host PC is able to connect to the running code via EtherCAT by use of EoE directly. The developer is able to monitor and manipulate all Simulink signals of the deployed model during runtime. Manipulation of constant block values is also feasible to e.g. investigate on different controller parameters online.

Optimized PWM Technique for Overmodulation Region in Vector Controlled High Speed Drives
Peter Stumpf, Sándor Halász, Budapest University of Technology and Economics, HU
An optimized PWM technique for the overmodulation region of two-level three-phase inverter-fed high speed ac drives is introduced in the paper. The optimization is elaborated for the lowest loss-factor, which is proportional to the square of rms value of current harmonics. In the paper the application of the technique is presented for closed loop controlled drives.

Dynamic Space Vector Modulation Control for Asymmetric Neutral Point Clamped Multilevel Inverter
Syed Inam Ul Murtaza Shah, Euro Engineering, D
A dynamic space vector modulation control is developed for a neutral point clamped three-level inverter for automotive applications. The developed SVPWM adresses changes in space-vector hexagon with asymmtery in DC battery voltages and implements controls for both symmetric and asymmetric dc battery voltages.

Short Pulse Transmission for SiC Communicating Gate Driver Under High Dv/Dt
Julien Weckbrodt, Stéphane Azzopardi, Safran, F; Nicolas Ginot, Christophe Batard, University of Nantes -IETR, F
A unidirectional data transmission for gate drivers based on a pulse transformer system is presented. We focus on pulse transformers integrated on gate drivers used for aeronautical applications. The integration of communication functions can achieve real time setting of the device for a better flexibility and efficiency. First, an accurate model has been developed to simulate the pulse transformer regarding the pulse shape. Then, an experimental circuit was designed to test short pulses transmission through the isolation of gate drivers.

Advanced Functionality of HVIC Technology for Intelligent Power Module
Jinkyu Choi, Wonhi Oh, Kinam Song, Samuell Shin,ON Semiconductor, ROK
Recently, many parts of the Power semiconductor devices are being replaced by IPM (Intelligent Power Module) in the motor control application. IPMs can help to reduce the number of parts and size, to simplify the design of systems, to be used wide-ranging application including industrial consumer electronics such as industrial motor.

Three-Level-Gate-Driver to Run Power Transistors in the Saturation Region for Junction Temperature Control
Johannes Ruthardt, Manuel Fischer, Julian Felix Wölfle, Nathan Tröster, Jörg Roth-Stielow, University of Stuttgart, D
One of the main influencing factors on reliability and lifetime of power semiconductor devices is the thermal stress induced by load alternation. Junction temperature control systems are able to reduce the thermal stress. To control the junction temperature an option to influence the power losses of the power semiconductor devices is required. The proposed three-level-gate-driver offers the option to run

power transistors in the saturation region and therefore to produce additional losses in order to control the junction temperature.

Improved Gate-Drive Unit for RC-IGBT to Overcome Load Current Disturbance in Static MOS-Control
Daniel Lexow, Holger Wiencke, Hans-Günter Eckel, University of Rostock, D
State-of-the-art RC-IGBT gate-drive units feature an immediate static MOS-control to react to a load current zero-crossing (CZC). This signifies, that after a current transition is detected, the gate-drive unit switches the RC-IGBT instantly into its low conduction loss state. Therefore, the occurrence of interfering oscillations during load CZC directly leads to an oscillating gate-drive voltage. The implementation of a blanking time into the gate-drive scheme to overcome this misbehavior is examined in ths paper.

Assessment-Based Flux Trajectory Optimization and Pulse Width Modulation for Flux Oriented Control: A Comparison
Axel Rothstein, Volker Staudt, Ruhr-University of Bochum, D; Carsten Heising, Avasition, D
This paper compares two concepts to guide the flux along a given trajectory. One is based on the well-known pulse-width modulation (PWM), the other one on the relatively new assessment-based flux-trajectory optimization (AFO). Both are able to dynamically handle unsymmetrical flux trajectories, and both can be implemented with low effort. The comparison highlights advantages and disadvantages of the control concepts.

AC-DC, DC-DC Converters

Resonant Inverter Stage in Modular Converter for Electric Vehicle Charging
Dimitar Arnaudov, Stoyan Vuchev, Dimitar Penev, Nikolay Hinov, Technical University of Sofia, BG
The following paperwork considers a resonant inverter stage for implementation in a realized on modular principle multi-phase converter for fast charging of electric vehicles. Model based design approach is proposed on the base of a developed model of the converter in MATLAB Simulink. Analytical expressions for design of the inverter stage are obtained. Considerations for the design procedure are discussed. Simulations and experimental examinations are carried out for verification of the inverter design.

Modeling and Investigation of Converter Modules Simultaneous Operation in Electric Vehicle Charging Systems
Stoyan Vuchev, Dimitar Arnaudov, Dimitar Penev, Nikolay Hinov, Technical University of Sofia, BG
The following paperwork considers a resonant inverter stage supplied by a controllable three-phase bridge rectifier as part of a multi-phase converter for fast charging of electric vehicles. Models of the two examined converters are developed in MATLAB Simulink. The conditions for simultaneous operation of the resonant inverter and the rectifier are discussed with respect to the output power control. Normalized characteristics of the two converters are obtained.

SiC-Hybrid Three Level T-Type Rectifier
Florian Störmer, Hans-Günter Eckel, University of Rostock, D
To fulfill the standards for harmonics for rectifiers operated in the public grid, power factor correction is mandatory. For single phase rectifiers, the PFC circuits are state of the art, while they are not commonly used for three phase rectifiers. In this paper, the efficiency of two level topologies with hybrid Si - SiC and full SiC devices is compared to a hybrid three level T-type solution of a Vienna type rectifier.

650 V Silicon Carbide MOSFETs in Totem-Pole Bridgeless PFC Design Achieves High Efficiency (80+ Titanium) Without Adding Complexity and Cost

Adil Salman, Edgar Ayerbe, James Solovey, Guy Moxey, Sei-Hyung Ryu, Adam Barkley, Wolfspeed, USA
650 V Silicon Carbide MOSFETs in Totem-Pole Bridgeless PFC Design achieves high efficiency (80+ Titanium) without adding complexity and cost.

GaN Power ICs and Off-the-Shelf Controllers Enable 150W, 500kHz AC-DC with 4x Power Density
Tom Ribarich, Stephen Oliver, Xiucheng Huang, Navitas Semiconductor, USA
This paper describes a 150W AC/DC power supply operating at 500kHz that uses GaN power ICs. The GaN power ICs enable high frequency switching and the high frequency switching enables a dramatic size reduction of the magnetic components. This results in a 4x increase in power density versus existing products in the marketplace today.

Active Phase Shifting Technique for Inductive Power Transfer (IPT) Systems
Malvika Kamat, Michael Patt, Technology Network Allgäu, D
The paper presents an active phase shifting technique for smooth variation of input power in IPT systems. This can be achieved by using a controlled rectifier. With the variation of fundamental amplitude of primary and secondary voltages along with changing phase angles between them, a control of input power can be achieved. Circumstances under which zero voltage switching of the primary and secondary side switching elements are lost have been observed. In addition, an idea for feedback-less control of phase angles has been proposed.

Analysis of a ZVS Synchronous Sepic/Zeta DC/DC Converter
Burkhard Ulrich, Baden-Wuerttemberg Cooperative State University Stuttgart, D
This paper presents soft-switching DC/DC converters based on Sepic/Zeta topologies. Zero voltage switching (ZVS) is achieved by using a synchronous converter topology and a suitable control of the switches. Converter operation is analyzed and the conditions for achieving ZVS are derived.Simulation results and measurements on a prototype converter are presented to verify the operating principle.

High Efficiency Shoot-Through Modulation Technique for Quasi-Z-Source DC/DC Converters
Yuba Raj Kafle, Graham E. Town, Macquarie University, AU
An improved shoot-through pulse width modulation (PWM) control technique for quasi-z-source DC/DC converters is presented. The improved modulation technique is derived from PWM control with shifted shoot-through, and reduces both switching losses and electromagnetic interference by reducing the number of switching transitions and increasing the proportion of soft switching transitions. The improved modulation technique also simplifies closed-loop control of the converter. A 500W quasi-z-source DC/DC converter prototype was built to verify the effectiveness of the proposed method.

DC-AC Converters

Reducing the dv/dt of Motor Inverters by a Two Leg Resonant Switching Cell
Thomas Fuchslueger, Hans Ertl, Technical University of Vienna, AT; Markus Vogelsberger, Bombardier Transportation, AT
Nominated for the Best Paper Award
Nominated for the Young Engineer Award
A concept for reducing the output dv/dt of SiC PWM motor inverters, which keeps high semiconductor switching speed is presented and analyzed. This is achieved by splitting up each phase leg into two legs which are gated slightly time delayed against each other and combining the output voltages by an interphase transformer. The stray inductance of this transformer in combination with an additional capacitor forms a resonant circuit which shows a cosine edge shaped output (motor) voltage at low dv/dt rates for a properly operation

SiC 2.5 MHz Switching Mode Resonant Halfbridge Inverter
Christoph Simon, Fabian Denk, Santiago Eizaguirre, Michael Heidinger, Rainer Kling, Wolfgang Heering, Karlsruhe Institute of Technology (KIT), D
We demonstrate a switching mode resonant halfbridge inverter with SiC-MOSFETs and an operating frequency of 2.5 MHz. The SiC-MOSFETs are IXFN50N120SIC from IXYS. The inverter operates in zero voltage switching mode (ZVS) and we present the design and measurements on a prototype. The losses are discussed with a loss model and related to different components, i.e. gate driver losses, losses of Rds(on) and the resonance circuit. The prototype achieves a high conversion efficiency above 95 %.

Analysis and Design of a Multilayer DC Bus With Low Stray Impedance and Homogenous Current Distribution
Asier Matallana, Jon Andreu, Jose Ignacio Garate, Iker Aretxabaleta, Iñigo Kortabarria, University of the Basque Country (UPV/EHU), ES
The aim of this work is to design a DC bus for silicon carbide power inverter. This converter works at high voltage and current levels with high frequencies signals, so a DC bus design with low impedance is necessary. Moreover, current has to flow homogeneously to avoid imbalances between bus capacitors. Theory of semiconductor parallelization has been applied in order to get a modular bus structure where the design symmetry and mutual coupling effect of layers produce a current balance over copper areas of the DC bus.

Replacing Si-IGBTs with SiC-MOSFETs in Low Voltage Grid Converters
Marius Kaufmann-Bühler, Hendrik Just, Michael Paluch, Sibylle Dieckerhoff, Technical University of Berlin, D
For low voltage, medium power grid converters two competitive converter technologies are available: state-of-the-art Silicon IGBTs and new SiC MOSFETs. For a comparison of the technologies, two available power modules with same package and similar ratings are examined in a 3-phase VSI. The effort of the SiC converter development is minimized by the replacement of the IGBTs by the SiC MOSFETs. A comparison shows that for the same efficiency at rated power the SiC converter can operate with 5 times the switching frequency of the IGBT converter.

A Polymer Optical Fiber Bus for Power Electronic Applications
Marek Galek, Siemens, D; Jacob Ranftl, Munich University of Applied Sciences, D
This work focuses on the design and the implementation details of a Polymer Optical Fiberbased communication network for power electronic devices. For this purpose, first therequirements needed in this area are presented in detail. Afterwards the design challengesand the implementation of specific components such as the optical splitter and transmittercircuit are shown and discussed regarding their characteristics in the industrial environment.

High-Inductive Zero-Voltage Commutations within Active-Neutral Point-Clamped Inverters
Felix Kayser, Jan Fuhrmann, David Hammes, Hans-Günter Eckel, University of Rostock, D
Improved three-level active neutral point clamped inverters allow an inductance between the upper and the lower half of the inverter. The failure current di/dt during the short is limited. But this protection inductance results in a high-inductive zero-voltage switching of the semiconductor. These switching conditions are unusual for high-voltage devices. Within this paper the behavior during switching of the semiconductor is described with the help of measurements and device simulations.

A SiC-based 15-Level Power Inverter for the Generation of Variable High Frequency Output Voltages
Sebastian Fahlbusch, Michael Meissner, Sebastian Klötzer, Felix Bröcker, Klaus F. Hoffmann, Helmut Schmidt University of the Federal Armed Forces Hamburg, D

A novel 15-level power inverter for the generation of variable high frequency output voltages is presented. The system, which can be used for the testing of inductive or capacitive components, is capable to generate output voltage waveforms up to 900 V and 50 kHz at 100 A in continuous and 200 A in pulsed operation. This results in an output apparent power of 40 kVA in continuous and up to 80 kVA in pulsedoperation. The setup, control strategy and measurement results are presented.

Loss Optimization for 48 Volt High Current Inverter
Matthias Ippisch, Dieter Gerling, Universityof the Federal Defense Munich, D
To realize high power levels in a 48 volt system, the inverter must be capable of providing very high current levels, while maintaining high efficiency and power density. Purpose of this work is the optimization of a low-voltage high power inverter. Switching losses of high current devices are investigated by means of different simulation methods and measurement. Together with the consideration of conduction losses, trade-offs will be highlighted, and an optimized design will be presented.

Common- and Differential-Mode Separators Including the FM Broadcasting Band
Karl Oberdieck, Jérôme Gossmann, Andreas Bubert, Rik W. De Doncker, RWTH Aachen, D
Noise reduction techniques depend on the propagation mode (Common mode (CM) or differential mode (DM)). Hence, the separation between CM and DM within measurements is essential. In SiC based power electronics, the electromagnetic emission increases significantly at frequencies above 10MHz. A CM/DM separator is a low-cost wideband and non-invasive laboratory equipment. In this paper implementation and design issues of CM/DM separators for the frequency range up to 110MHz are presented.

Accurate Self-Identification of Inverter Nonlinear Effects in AC Drives
Simon Wiedemann, Ralph M. Kennel, Technical University of Munich, D
This paper presents a novel self-identification method which characterises accurately the nonlinear voltage distortions of a voltage source inverter. The proposed method requires no additional test equipment and no position sensor which makes it together with its simplicity andhigh accuracy particullary suitable for industrial applications.

Special Converters

Strategy for Reducing Oscillations in Power Electronic Circuits Using Gate Control
Lars Middelstaedt, Andreas Lindemann, Otto-von-Guericke-University, D
This paper addresses the issue of reducing switching oscillations in a basic power electronic commutation cell. Based on previous publications, an analytical model of the turn-off process is presented leading to an optimization strategy. According to this, an optimum can be found allowing a fast switching transition and thus small switching losses as well as reducing the oscillation amplitude to a minimum and hence, improving electromagnetic compatibility characteristics.

The newest ST's Super-Junction Power MOSFET Technology for the Best Efficiency in Air Conditioning System
Carmelo Parisi, Carmelo Mistretta, STMicroelectronics, I
Air conditioning system requires energy efficiency improvement and it is driving the semiconductor industry to develop efficient power transistors. STMicroelectronics has developed the newest Super-Junction Power MOSFET technology in MDmesh DM2 fast recovery diode and together with the Trench Field Stop IGBT one, offers a double option to achieve the energy efficiency improvement target. A detailed comparison between the two technologies is provided in a motor drive application up to 1.2kW.

High Efficiency Three-Level Simplified Neutral Point Clamped (3L-SNPC) Inverter with GaN-Si Hybrid Structure
Alexander Lange, Jennifer Lautner, Bernhard Piepenbreier, Friedrich-Alexander-University Erlangen, D
Nominated for the Young Engineer Award
In this paper, a new Three-Level Simplified Neutral Point Clamped inverter with GaN-Si hybrid structure for motor drive applications is introduced. This topology allows the utilization of fast switching capability of new wide bandgap power devices with low blocking voltage together with conventional silicon power devices with high blocking voltage in one system. Thus, the advantages of fast switching power devices
and multilevel inverter topologies are combined and the efficiency can be improved.

Reducing Astable Relay Power Consumption by the Use of a Constant-Current Buck Converter
Michael Heidinger, Christoph Simon, Fabian Denk, Rainer Kling, Wolfgang Heering, Karlsruhe Institute of Technology (KIT), D
Relays are essential components for the safety of power converters. Solar AC inverters require two astable relays per line, resulting in eight relays on the AC side. As the race for efficiency in solar converter continues reducing every watt of power becomes mandatory. Relays require a high power at turn on whereas in connected state a reduced lower drive current is sufficient. Based on those needs, an integrated constant current buck relay driver circuit is proposed; it optimizes the system efficiency of power converters while ensuring reliable operation.

Effect of Spurious Resonant Modes on the Operation of Radial Mode Piezoelectric Transformers
Jack Forrester, Jonathan Davidson, Martin Foster, University of Sheffield, GB
This paper analyses the intentional and unintentional resonant vibration modes of operation in radial mode piezoelectric transformers (PTs).

Fuzzy Logic Based Adaptive Controller for AC/DC Boost Converters
Andrea Morici, Infineon Technologies, D; Zain Bin Tariq, Technical University of Munich, D
AC/DC LED drivers with digital boost converters implement bus voltage regulation emulating analog controllers. This approach has the disadvantage to be computationally expensive. This paper presents a fuzzy logic based adaptive controller for bus voltage regulation. It highlights the lean computation of the fuzzy controller and shows comparative results to a standard analog controller. Simulations confirm the suitability of the proposed methodology for AC/DC boost converters in particular for cost sensitive applications such as in lighting.

Power Supply System with Integrated Energy Storage for Supeconducting Magnets
Maria Papamichali, Emilien Coulinge, Francisco Freijedo, Drazen Dujic, EPFL - Ecole Polytechnique Fédérale de Lausanne, CH
This paper describes topological implementation of a new two-quadrant family converter with supercapacitor-based energy storage required for the new superconducting magnets of CERN's High-Luminosity Large Hadron Collider, considering operating cycle and superconducting magnet parameters. Converter control design and energy management are presented and verified through simulations of a complete system, providing insight for the future system design.

Novel Thyristor-Based Pulsed Current Converter for a Medical Application - a Conceptual Introduction
Stefan Wettengel, Lars Lindenmüller, Steffen Bernet, Technical University of Dresden, D; Ulrich Schramm, Florian Kroll, Florian-Emanuel Brack, Helmholtz-Zentrum Dresden - Rossendorf, D; Jörg Pawelke, OncoRay - National Center for Radiation Research in Onc
Nominated for the Young Engineer Award

A novel ion beam radiation therapy apparatus employing pulsed high magnetic field coils for transporting the ion beam has been proposed. In this paper a new pulsed current converter topology is introduced, which can be used as a pulsed power supply for the therapy apparatus.

Power Electronics in Automotive

Robust Automotive 40V Power Mosfets for Safer Vehicles
Filippo Scrimizzi, Giuseppe Longo, Giusy Gambino, STMicroelectronics, I
Advanced MOSFET tecnnology for BLDC 3 phases systems provedes the best trade off between very low RDSon and switching behavior, making ST solution one of the best in the market.

Large Capacity Power Module Packaging Technology For Automotive Inverter Applications
Yuki Hata, Shoji Saito, Seiichiro Inokuchi, Shinji Hatae, Mitsubishi Electric, J
This paper is about the IGBT modules for inverter application as automotive power train. Conventionally, in the inverter system requiring high power, there are several problems that are the difficult layout and the large self-inductance constraints due to increasing the power module sizing. And high capacity power module needs several IGBTs in parallel which has current imbalance. This paper addresses new packaging technology which can solve these issues.

Analysis of a Multiphase Multi-Star PMSM Drive System with SiC-Based Inverter for an Automotive Application
Stefan Piepenbreier, Fabian Streit, Maximilian Hofmann, Fraunhofer Institute IISB, D; Julian Berlinecke, Robert Plikat, Volkswagen, D; Nicola Burani, Roland Bittner, Semikron Elektronik, D; Serhij Matichyn, EPCOS, D
A three-phase and a symmetrical nine-phase drive system for automotive application will be presented. Both systems are designed to have the same system performance and are analyzed regarding their key components. A two-level, three-phase Intelligent PowerCore (IPC) is proposed as B6 inverter unit enabling scalable multiphase hardware architectures. Key parameters like footprint, power density, etc. will be addressed. The potential of reducing the bulky and costly dc-link capacitor by using a multiphase topology will be analysed and simulated.

Supercapacitors-Based Engine Start Battery Support Device with Active Control
Kaspars Kroics, Riga Technical University, LV
The paper describes the design of supercapacitor based start battery support device that is used to improve engine starting of internal combustion engine, extend lifetime of starting battery and eliminate voltage drop during starting process. The addition storage is connected through controllable switch to increase stored energy. A prototype is tested under real conditions; experimental results are registered and included in the paper. The results show that such device provides successful cold cranking.

A Modular DC/DC Converter to Couple a Double Layer Capacitor to the Automotive High Voltage Grid for Short Time Energy Storage
Bastian Strauß, Andreas Lindemann, Otto-von-Guericke-University, D
Bi-directional DC/DC-converters are used in electric vehicles for controlled power flow between different energy storages or electric loads. In order to relieve the traction battery of dynamic stresses by power peaks and therefore to ensure an extension of battery lifetime, dynamic power reserve can be provided by controlled storages using bidirectional DC/DC-converters. This paper deals with a laboratory setup to develop and investigate bi-directional modular DC/DC-converters for automobile applications using wide band gap semiconductors.

Design Optimization of a Three-Phase Bidirectional Dual Active Bridge DC/DC Converter for E-Vehicles Applications

Felipe Bandeira da Silva, Tobias Rafael Fernandes Neto, Federal University of Ceará, BR; Eduardo Façanha de Oliveira, Peter Zacharias, University of Kassel, D;
This paper presents an isolated bidirectional DC-DC converter for the use in electrical vehicles on-board power supply systems. Due to the high input/output voltage range and the high power level, the three-phase Dual Active Bridge (DAB) is chosen. In order to ensure the best performance concerning losses and volume, an optimal design is carried out by changing several parameters.

On-Chip Current Sense: A New Approach for Over Current and Short Circuit Detection for Automotive Main Inverter
Rony Karim, Infineon Technologies, D
This paper presents the advantages of the integrated On-Chip current sense on an IGBT compared to the classical DESAT detection for Over Current Protection (OCP). The working principle of On-Chip current sense and a possible implementation method together with a gate driver is described in this paper.

Evaluation of Infineon HybridPACKTM Drive with Optimized Integrated Capacitor/Bus DC Link for High Performance Inverter Applications
Michael Brubaker, Terry Hosking, SBE, USA; Michael Mazzola, Somasundaram Essakiappan, Ehab Shoubaki, Madhav Manjrekar, Energy Production and Infrastructure Center, USA; Tomas Reiter, Infineon Technologies, D
The Infineon HybridPACK module was evaluated using a SBE capacitor/bus DC link. The testing demonstrated the importance of low ESL to achieve maximum efficiency with fast switching at full voltage, but was test equipment limited to 50kW. Power testing up to 150kW is performed using 750V and 1200V IGBT versions of the HybridPACK Drive along with 500V and 750V variants of the SBE test kit. This work provides critical thermal data to establish a high performance inverter baseline.

Multiple Comb Pattern Based Living Object Detection with Enhanced Resolution Design for Wireless Electric Vehicle Chargers
Van X.Thai, Jun H. Park, Seog Y. Jeong, Chun T. Rim, Gwangju Institute of Science and Technology, ROK
A living object detection (LOD) system for wireless electric vehicle (EV) chargers including multiple comb-pattern capacitive sensors is proposed in this paper. The capacitance changes of the sensor caused by a nearby living object is sensed by a specially built parallel-resonant circuit, which verifies the appearance of the living object. A prototype of the proposed LOD system with the sensing sensitivity of 30 % is installed on a transmitting pad of a 6.6 kW wireless EV chargers proves the validity of the design.

Power Modules for Electric Vehicles SRM Converter
David Cabezuelo, Jon Andreu, Iñigo Kortabarria, Edorta Ibarra, Iñigo Martinez de Alegría, University of the Basque Country (UPV/EHU), ES
Asymmetrical half-bridge and C-Dump are considered best topologies for Switched Reluctance Machine converter. The main goal of this work is to show a comparison of both topologies. Simulation results are provided to highlight their technical and performance differences. In addition, ratings of commercial power modules, suited for these topologies, are summarized. Advantages and disadvantages of such topologies will be highlighted taking into account automotive requirements.

Power Quality, Power Transmission

Active Damping for Power Quality Improvement in Grid-Connected Current-Controlled Voltage Source Converters
Lorenzo Giuntini, Andrea Mannuccini, GE Consumer & Industrial, CH
Active damping schemes have known a variety of applications. This paper discusses the benefits of one such scheme when applied to grid-connected voltage source converters. Particularly, it includes

experimental results from applying active damping to the front-end rectifier in a double-conversion UPS. The proposed control technique improves input performance both in terms of power factor and current distortion, while ensuring stability and robustness. Actual performance has been verified under sinusoidal as well as distorted grid voltage.

Harmonic Current Control in DG-Connected Network Using Proposed Pulse Adaptive VSI
Navid Daniali, Euro Engineering, D
A new PWM scheme, suitable for being used in DG interface is proposed at this paper. By using proposed pulse adaptation method in conventional voltage-control-based method of DG, current harmonics in network could be compensated without adding to the complication of the main power control level, because this method, unlike the conventional harmonic compensation methods, applies pulse shaping process in PWM level

Dynamic Performance Evaluation of a dual UPQC Operating Under Power Quality Disturbances
Sérgio Augusto Oliveira da Silva, Leonardo Bruno Garcia Campanhol, Vinicius de Souza, Federal University of Technology Parana, BR
This paper presents the dynamic performance evaluation of a 3Ph UPQC deployed to perform the series-parallel connection to electrical system. Since the UPQC operates using a dual compensating strategy, the parallel converter feed the load as a sinusoidal voltage source. Thus, the overall system dynamic is improved because the series converter does not need any direct control to compensate the utility disturbances, as conventionally occurs in the control of UPQCs. The UPQC is subjected to power quality events to evaluate its dynamic behavior.

Active Filtering of DC Ripple Currents Between Converter and Low-Resistive DC Load
Sebastian Raab, Ansgar Ackva, University of Applied Sciences Würzburg-Schweinfurt, D
This paper introduces a power electronic control element consisting of fast switching SiC MOSFETs for compensating ripple currents emerging when coupling the DC link of aconverter to low-resistive, low-inductive high current load/source like lithium-ion batteries.Those ripple currents cause additional losses and can damage components exposed to it. Using the application presented,packaging dimensions of heavy, costly passive filters can be lowered and thus the losses arising inside them.

Dynamic Control and Design of a Modular Power Flow Controller for HVDC Networks with Fault Clearing Capabilities
Daniel Dinkel, Claus Hillermeier, Rainer Marquardt, University of the Federal Armed Forces Munich, D
Future HVDC networks require an optimized converter topology for control of energy distribution. The proposed converter meets the requirements of connecting any number of transmission lines with different voltage levels and lengths, full control of power distribution and scalability.

Multi-Terminal HVDC Grid Control Using a Fictitious, Model Based Machine Set
Steffen Menzel, Alexander Ernst, Johannes Adler, Bernd Orlik, University of Bremen, D
For future wide area grids, which are needed to make further offshore wind farms accessible, a reliable and stable multi terminal HVDC grid is proposed. Using HVDC avoids the transfer of large amounts of reactive power related to a conventional HVAC grid. This work shows an approach of controlling multiple voltage source converter stations using a fictitious, model based machine set for each converter station. The dynamic behaviour of this multi terminal HVDC system is analysed in simulation.

Research on Solid State Circuit Breaker Based on SiC MOSFET with Soft Switch off Method
Haihong Qin, Ying Zhang, Yaowen Dong, Kefeng Xu, Shishan Wang, Nanjing University of Aeronautics and Astronautics, CN; Chaohui Zhao, Shanghai DianJi University
In order to ensure the safe and reliable operation of silicon carbide power devices and improve the reliability of silicon carbide based DC solid state circuit breakers, the short circuit capability of silicon

and silicon carbide MOSFET is analyzed and compared. In addition, gate-source voltage clamp methods are elaborated and compared. Combined with desaturation detection, a "soft turn-off" short-circuit protection method based on source parasitic inductance is proposed. Finally, a DC solid state circuit breaker prototype is built for experimental verification. Experimental results show that the proposed method can not only reduce the voltage stress of the power device, but also suppress the short circuit current.

Software Tools and Applications

Virtual Prototyping of Applications for Wide Bandgap Power Devices Using Physically Scalable SPICE Models in Keysight Advances Design System
Mehrdad Baghaie Yazdi, ON Semiconductor Germany, D
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Predicting ZVS Behavior of Resonant Converters Using a Fast and Effective Calculation Method
Christian Oeder, Markus Barwig, Thomas Dürbaum, Friedrich-Alexander-University of Erlangen, D
Based on the needs for high power densities and ultra-high efficiencies, the popularity of resonant converters has never been this high before. By pushing the upper limit of switching frequency to higher levels continuously, their beneficial
soft-switching ability is massively endangered. Circuit designers are aware of this fact, but serious ZVS investigations are often missing within today's optimization routines. This paper proposes two calculation methods allowing fast but accurate prediction of resonant converters' ZVS behavior.

A Novel Combination of Algorithms for Accelerated Convergence to Steady-State
Benedikt Kohlhepp, Jens Göttle, Eva Schmidt, Thomas Dürbaum, Friedrich-Alexander-University of Erlangen-Nuremberg, D
This paper presents a novel combination of algorithms to calculate the steady-state solution of switch mode power supplies through simulation. It combines a mixture of numerical and analytical methods to reach the steady-state operation which is important for power converter design. The proposed simulation procedure is applied to an advanced DC-DC converter to prove its reliability and performance.

A Novel Detailed Analysis of the Boost Converter Utilizing Nonlinear Inductance and Capacitance
Panagiotis Mantzanas, Erdi Bayrakdar, Daniel Kübrich, Thomas Dürbaum, Friedrich-Alexander-University of Erlangen, D
Magnetic components belong to the most important elements in power supplies. Such components exhibit a nonlinear inductance, an effect that can also be used beneficially. Furthermore, the parasitic capacitances of semiconductor devices introduce additional nonlinearities. Only by considering these nonlinearities a proper converter design is guaranteed. Thus, this paper proposes a novel calculation method for the boost converter with nonlinear inductance and capacitances. The proposed method combines a high computational efficiency and accuracy.

Performance Analysis of IGCT Clamp Circuit and Thermal Loss Modeling of IGCT Based Converters for High Power Applications IGCT Based Converters for High Power Applications
Madhan Mohan, Anup Kavimandan, ABB Global Industries and Services, IN; Umamaheswara Vemulapati, Evgeny Tsyplakov, Munaf Rahimo, ABB Switzerland, CH
IGCTs have become the device of choice for high power applications, low losses and high reliability. They have been widely equipped in many Voltage Source Converters (VSC) for industry applications. This paper presents the performance evaluation of IGCT Clamp Circuit in terms of losses, as a function of load current in SEMIS (Semiconductor Simulation Tool) simulation tool. The proposed

method based on dynamic measurement test data yields an accurate, yet computationally efficient method of loss calculation.

SMPS Protection Against Lightning Effects
Claudio Mazzurco, STMicroelctronics, I
Through the deeply explanation of the atmospheric phenomenon, we aim to model the lightning effect on SMPS (Switch Mode Power Supply) applications protected by a MOV (Metal Oxide Varistor) and propose a new Electrical Design Aided (EDA) model which base the analysis on computations carried out on the first and the third V/I quadrant representation instead of just using the first one.

Power Loss Breakdown in BLDC Drives Applications Using MATLAB
Hrach Amirkhanian, Infineon Technologies, USA; Steve Oknaian, Infineon Technologies Americas, USA
A new method is proposed to calculate the power loss breakdown in BLDC motor drive applications with different control methods . MATLAB derives the FET channel and body diode currents from the phase current and calculates all the losses related to the inverter power board, including conduction, switching and body diode losses for the power FETs. The results show that body diode losses are significant in trapezoidal control method. Using Schottky-like MOSFETs is preferable. Power measurements verify the calculations.

Statistical Modelling Method for Active Power Components Based on Datasheet Information
André Andreta, Yves Lembeye, Jean-Christophe Crébier, University Grenoble Alpes - G2Elab, F; Luiz Lavado Villa, LAAS - CNRS, F
This paper presents a methodology to derive models of active power components based on statistical theory and datasheet parameter extraction. The models have, as objective, to provide reliable mosfet data of VGD, VGS and ID for nominal operating temperature range based only on datasheet parameters. For achieving that, statistical learning theory is used to fit models in a reliable way. Besides predicting static operation points, the proposed model can be used to estimate dynamics and switching losses in power switches.

Fast Solver to Get Steady-State Waveforms for Power Converter Design
Guillaume Fontes, Regis Ruelland, Alvaro Morentin, Guillaume Delamare, Nicolas Videau, Adel Ziani, Power Design Technologies, F; Thierry Meynard, University de Toulouse, F
This work shows that a frequency-domain solver based on a Modified Nodal Analysis of the circuit can replace tedious analytical computations to estimate electrical quantities for power converter design process. It allows power electronics designer to get steady-state waveforms much faster than with a time-domain solver and harmonic spectrum is obtained with a very good accuracy.

System complexity reduction approach in the modelling of a discrete power device
Daniela Cavallaro, Alessandra Cascio, Giuseppe Greco, STMicroelectronics, I
Power devices modeling poses several challenges related to the intrinsic complexity of wide-area silicon structures usually featuring several interacting heterogeneous sub-parts. Mutual interactions, intrinsic non-linearity, feedback loops and strong dependency from boundary conditions are most frequent modeling complications. The need of modelling such large components implies the definition of modelling approaches allowing the whole system complexity reduction, to make it easy analyzable through standard spice-like simulators.

Automated Medium Voltage Virtual Test Bench Using Hardware-in-the-Loop
Emmanuel Frappé, Alain Dutrey, François Malrait, Schneider Electric, F
Altivar 6000 is a variable speed drive developed to address MV market. We decide to setup an automatic Hardware-in-the-Loop test bench for unitary tests, system tests, and non-regression tests of control/command hardware and software functions. The drive control board is connected through

dedicated interface to the real-time environment running physical models of the MV Power system, motor, and application. The bench lies on computer engineered environment for automatic configuration and allows to test 216 product references.

Reliability SiC Devices

Practical Aspects and Body Diode Robustness of a 1200V SiC Trench MOSFET
Thomas Basler, Daniel Heer, Dethard Peters, Reinhold Schörner, Infineon Technologies, D; Thomas Aichinger, Infineon Technologies, AT
The paper investigates differences between IGBT and SiC trench MOSFET and physical aspects which go hand in hand with new devices, e.g. the more pronounced short channel effect or the VGS(th) hysteresis. The impact on device characteristics is explained and the robustness of the device under short circuit and body diode surge current and commutation SOA is shown.

High Dynamic Stress on SiC Trench MOSFET Body Diodes and their Behaviour
Andreas März, Teresa Bertelshofer, Mark-M. Bakran, University of Bayreuth, D
Nominated for the Best Paper Award
Nominated for the Young Engineer Award
This paper investigates state-of-the-art SiC trench MOSFET body diodes under high dynamic stress and during reverse-recovery in parallel configuration. Measurements on SiC MOSFET body diodes under high dynamic stress show the effect of a clamping of the drain-source-voltage together with a measurable of increase of the charge during reverse-recovery.

Reliability and Ruggedness of SiC Trench MOSFETs for Long-Term Applications in Humid Environment
Ingo Voss, Thomas Basler, Peter Friedrichs, Roland Rupp, Infineon Technologies, D; Thomas Aichinger, Infineon Technologies, AT
SiC Trench MOSFETs are planned to be used in long-term outdoor applications like solar and drives. This means that the reliability of SiC Trench MOSFETs has to be ensured and verified by extended standard reliability tests and application relevant tests. In this paper, the performed tests and the results after stress are presented. The results show that the investigated SiC Trench MOSFET has a high reliability of gate oxide and can withstand humidity and operate under short-circuit condition.

Investigation on Reliability of SiC MOSFET Under Long-Term Extreme Operating Conditions
Tien Anh Nguyen, Nidhal Boucenna, Denis Labrousse, Gérard Chaplier, Stéphane Lefebvre, SATIE-CNAM, F; Stéphane Azzopardi, Safran TECH, F
To reproduce the aging state of power semiconductor devices for real operating conditions, the aging process under long-term extreme operating condition (short circuit, unclamped inductive switching) was performed. The study focuses on discrete SiC MOSFET. We measure different aging indicators during aging process. The results highlight a similar evolution of these indicators measured in both stresses. A small increase of gate leakage current (900fA) was detected before failure. This leakage current is related to the degradation of oxide layer.

High Humidity, High Temperature and High Voltage Reverse Bias - A Relevant Test for Industrial Applications
Joni Jormanainen, Jonny Ingman, Aleksi Vulli, ABB Oy, FI; Elena Mengotti, Thiago Batista Soeiro, Enea Bianda, David Baumann, Thomas Friedli, Alexander Heinemann, ABB Switzerland, CH
The importance of the High Humidity, High Temperature and High Voltage Reverse Bias test (H3TRB-HVDC) for semiconductor reliability is shown in this paper. Results from different devices and manufacturers are presented. The conditions used in the tester are T=85° rH=85% and stress voltage 80% of the rated value. H3TRB-HVDC should become a common test for SiC semiconductor suppliers as humidity ruggedness of power devices is an essential feature for industrial applications.

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Power Modules & Smart Driver

Impact of Load Profiles on Power Module Design - a Detailed Analysis Based on 7th Generation of IGBT and Diode Technology
Stefan Buschhorn, Anastasia Brodt, André Lenze, Alexander Philippou, Christian Jäger, Johannes Laven, Benjamin Sahan, Christian Müller, Infineon Technologies, D
The interaction in-between load profile and power-module lifetime is analyzed. Major differences in temperature ripples and distribution are highlighted and consequences for the power module are derived. Based on an exemplarily chosen system, the resulting power-module lifetime is concluded. It is demonstrated that, with respect to the application demands, temporary overload operation at high junction temperatures is sufficient and continuous operation at, e.g., 175 °C does not provide any additional advantage.

A Novel Insulation Technology for Gate Drivers
Karsten Fink, Andreas Volke, Power Integrations, D; Matthias Kurth, Michel Graby, Power Integrations, CH
This paper describes a novel isolation technique and explores the qualification process for the revolutionary lead-frame-based coreless Pulse Transformer used in integrated circuit-based gate driver.

Directly Cooled HybridPACK Power Modules with Ribbon Bonded Cooling Structures
Andre Uhlemann, Erwin Hymon, Infineon Technologies, D
In this paper a new way of direct fluid cooling for power modules is introduced to the market that gives an alternative to the pin fin base plates fabricated with MIM (Metal injection molding) or forging technologies.The new cooling concept uses flat base plates (nickel plated copper base plates) and ribbon bonded cooling structures. It is very flexible and offers a fast implementation of customer specific design with an optimized thermal performance being comparable with results from conventional pin fin base plates.

Enhanced Module Design with DPD Technology
Roberto Bellu, Christian Göbl, Andreas Maul, Clemens Vennebusch, SEMIKRON Elektronik, D
This paper introduces 'Direct Pressed Die' (DPD) technology, starting from the well-known SKiiP pressure contact technology and showing how it is possible to further exploit the pressure contact concept. The elimination of wire bonds, introduced with SKiN technology in 2011, enables the possibility to press where it is mostly needed: directly onto chips. This grants an excellent thermal resistance without rigid connection between substrate and heatsink or baseplate, just a thin deposition of thermal interface material.

Direct 2-Way Coupled Electro-Thermal Simulation of Temperature and Current Distribution in Power Devices
Marina Montaine, Uwe Scheuermann, SEMIKRON Elektronik, D; Martin Hanke, CADFEM, D
Thermal measurements based on the VCE(T)-method only deliver an area related average temperature of the devices with no information about Tmax. For realistic identification of hot spots coupled thermo-electrical simulations must be applied. We introduce a method of direct coupled thermo-electrical simulation in ANSYS, which takes into account the temperature depended current distribution given by the VF(IF,Tj)-characteristic of the device as well as the impact of parasitic resistances along the current paths of paralleled devices.

Reverse Conducting IGBT's

Short-Circuit Behavior of 6.5 kV RC-IGBT
Holger Wiencke, Daniel Lexow, Hans-Günter Eckel, University of Rostock, D

This paper presents measurements of the short-circuit behavior of 6.5 kV high power Reverse Conducting IGBT (RC-IGBT). Differences between short-circuit types I-IV are investigated for RC-IGBT and compared with conventional IGBT. The results are discussed concerning the optimized gate-drive pulse pattern for RC-IGBT usage.

New Transfer Mold SMD Type IPM with Integrated RC-IGBT, Bootstrap Diode and Capacitor
Yazhe Wang, Maki Hasegawa, Mitsubishi Electric Corporation Power Device Works, J
A new transfer mold SMD type IPM developed for small capacity motor drive in home appliance products that compact size and high reliability are pursued is presented in this paper. By utilizing new packaging technology and thin wafer RC-IGBT the new SMD type IPM successfully incorporated not only 3-phase IGBT bridge and gate-driver ICs but also BSDs and Bootstrap Capacitors (BSCs) into a very compact surface mount type package that can dramatically minimize overall size and complexity of the inverter drive system.

The Series of 7th-Generation "X Series" RC-IGBT Modules for Industrial Applications
Akio Yamano, Hiroaki Ichikawa, Misaki Takahashi, Toru Ajiki, Yuichi Onozawa, Seiichi Takahashi, Makoto Isozaki, Soichi Okita, Yasuyuki Kobayashi, Osamu Ikawa, Fuji Electric, J
We describe the series of our newly 7th-Generation "X Series" RC-IGBT Modules for Industrial Applications.

4.5kV Rupture Resistant Press Pack IEGT
Raita Kotani, Tetsuya Nitta, Naoto Tsukamoto, Hideaki Kitazawa, Motoaki Kitagawa, Tomohiro Kawano, Toshiba, J; Georges Tchouangue, Toshiba, D
A 4.5kV class Press Pack IEGT (PPI) with an improved rupture resistance is presented. That capability is not only achieved by increasing the thickness of the ceramic package, but also by optimizing the parts inside the package. The rupture resistance of the new package could achieve 13.3 MA2sec which is 1.7 times of that of the conventional package.

New Low Loss Phase Control Thyristors for Medium Current UHVDC Transmission
Sascha Populoh, Chunlei Liu, Marco Bellini, Kenan Tugan, Urban Meier, Jan Vobecky, ABB Switzerland, CH
The presented new generation of 8.5 kV class Phase Control Thyristors (PCTs) in package with 119 mm pole piece features reduced ON-state voltage VT through optimized wafer thickness, resistivity and cathode design. Additionally, dV/dt and tq ratings were improved as well in the whole range of VT/Qrr values relevant for HVDC and industrial applications. This device completes the new generation PCT platform of ABB with rating currents of 1.5, 3 and 6 kA.

High Frequency Converters

Optimisation of an Integrated Bidirectional Interleaved Single-Phase Power Factor Corrector
Johan Le Lesle, Rémy Caillaud, Nicolas Degrenne, Roberto Mrad, Stefan Mollov, Mitsubishi Electric R&D Centre, F; Florent Morel, Cyril Buttay, Christian Vollaire, Laboratoire Ampère, F
This paper presents a design methodology for a full-bridge interleaved Power Factor Corrector (PFC) converter. The objective of this work is to design a highly integrated converter.This work highlights the fact that is possible to achieve Zero Voltage Switching (ZVS) with high inductor current ripple operation. Moreover interleaving technique permits to reduce EMI filter size. Hence, combining both techniques leads to the design of a high efficiency and high power density converter.

Multi-MHz LED Drivers: Design for Lifetime and Reliability
Riccardo Pittini, Thomas Andersen, Toke M. Andersen, Mickey Madsen, Martin Rødgaard, Jakob Mønster, Nordic Power Converters, DK

LED power supply lifetime is often the limiting factor for LED luminaries. This paper presents the design of a 60W electrolytic-free commercial outdoor LED driver operating at multi-MHz switching frequencies which allow minimizing passive components. Lifetime and reliability predictions based on both mathematical models and manufacturer data are integrated into the design process in order to achieve a lifetime above 130000 hours. Results highlight how high switching frequencies can help to increase the power supply lifespan and reliability.

High-Frequency and High-Density Design of all GaN Power Supply Unit
Ruiyang Yu, Qingyun Huang, Tianxiang Chen, Alex Q. Huang, University of Texas at Austin, USA; Tom Ribarich, Navitas Semiconductor, USA
This paper presents the design of high frequency high efficiency all GaN FETs solution for 240Vac to 48Vdc 3.2kW power supply unit (PSU).

Comparison Between an Interleaved Boost Converter Using Si MOSFETs Versus GaN HEMTs
Simon Ravyts, Mauricio Dalla Vecchia, Jeroen Zwysen, Giel van den Broeck, Johan Driesen, KULeuven, BE
The paper compares a three leg interleaved Boost converter based of 300 W for a BIPV application. One prototype uses regular Si components, the other prototype is built using wide-bandgap components. Evaluation will be based on efficiency, compactness and thermal behaviour.

A Novel AC Direct Linear LED Driver with Unity Power Factor, Low Input Current THD, Low Light Flicker and Low Profile
Jie Fu, Gang Wang, Shan Wang, Zhiquan Chen, Liang Shi, Philips Lighting Research Center, CN
A novel low light flikcer and low profile LED driver with unity power factor, low input current THD is proposed in this paper for AC direct lighting. Finally, simulations and prototype experiments verified the proposed LED driver.

GaN Devices

High Power Nanosecond Pulse Laser Driver Using an GaN®FET
John Glaser, Efficient Power Conversion (EPC) Corporation, USA
This work describes a laser driver using commercial GaN FETs to achieve a high power, high speed pulse laser driver capable of operating from an 80 V bus, and can generate current pulses into a laser diode of 60 A peak current with a 5 ns duration.

Very High Current Wire Bondable and Embeddable GaN E-HEMT Devices for High Power Applications
Larry Spaziani, Di Chen, Lucas Lu, GaN Systems, CA
>>> zurück gezogen

6.78 MHz Multi Amplifier and Transmit Coil eGaN® FET based Class-E Wireless Power System Evaluation
Michael de Rooij, Yuanzhe Zhang, Efficient Power Conversion (EPC), USA
A large area wireless power architecture using multiple high Zout class E amplifiers driving partially overlapped coils is presented. Experimentation shows that high Zout amplifiers inherently isolate from each to balance load sharing for receivers that straddle across two or more coils. Only eGaN FET based class E amplifiers can simultaneously achieve high efficiency and high output impedance making them ideal for this application.

Towards Highly-Integrated High-Voltage Multi-MHz GaN-on-Si Power ICs and Modules

Stefan Moench, Oliver Ambacher, Richard Reiner, Beatrix Weiss, Patrick Waltereit, Rüdiger Quay, Fraunhofer-Institute IAF, D; Thomas Kaden, Robert Bosch, D; Ingmar Kallfass, University of Stuttgart, D
This work discusses integration and packaging approaches using 600 V GaN-on-Si technology. The influence of a common conductive Si substrate on circuit performance is investigated. A 300 V dc-dc converter (97 % efficiency) is built to compare separately source-connected and common semi-floating substrate terminations of the high-/low-side circuits. Operation of a GaN-based half-bridge with integrated gate-driver on a common substrate is demonstrated, emulating a fully-integrated solution.

System Reliability

Partial Discharge Measurement in a Motor Winding Fed by a SiC Inverter - How Critical is High dV/dt Really?
Marco Denk, Mark M. Bakran, University of Bayreuth, D
This paper develops a sensor system to investigate partial discharge in a motor winding during PWM operation of a SiC inverter with high dV/dt. It is found that even in PWM operation with 41 kV/µs partial discharge only appears if the PMW voltage exceeds the critical voltage found in a state of the art PD test. No additional effect of the high dV/dt was observed! This highly interesting outcome is traced back to material properties and the design of the winding. It opens up new options for SiC in motor drives.

Evaluation of Ag-sinter and CuSn-TLP Based Joining Technologies on Lead Frame
Alexander Otto, Tim Schröder, Rainer Dudek, Mario Baum, Ralf Döring, Sven Rzepka, Wei-Shan Wang, Maik Wiemer, Jyothi Jennifer Kurian, Fraunhofer-Institute ENAS, D; Kei Murayama, Kiyoshi Oi, Tetsuya Koyama, Shinko Electric Industires, J
In this paper, an Ag-sinter based joining technology for chip to lead frame die attach is investigated. The focus will be set on the evaluation of different sinter process parameters, i.e. sinter temperature and pressures, with respect to their reliability. For this reason, characterization of the joint layer and power cycling tests were performed in conjunction with FE analyses. The results will be detailed in the paper and compared to classical solder joint technologies.

On-line Health Monitoring of Wire-Bonded IGBT Power Modules using On-State Voltage at Zero-Temperature-Coefficient
Nicolas Degrenne, Stefan Mollov, Mitsubishi Electric R&D Centre Europe, F
Monitoring the health of IGBT power modules is an enabling technology for predictive maintenance. This paper proposes and tests a circuit and method to measure on-line the on-state voltage at the Zero-Temperature-Coefficient (ZTC) current value. We demonstrate the experimental feasibility to monitor the electrical resistivity increase that is associated with the wire-bond degradation of IGBT power module rated at 150A/1200V driving a sinusoidal current.

First Results of Development of a Lifetime Model for Transfer Molded Discrete Power Devices
Guang Zeng, Oliver Wenzel, Josef Lutz, Chemnitz University of Technology, D; Ludger Borucki, Oliver Schilling, Infineon Technologies, D
Transfer molded devices have shown higher power cycling capability compared to power modules. There is however still a shortage of investigation on power cycling capability of discrete package regarding lifetime impacting parameters. In this work, IGBTs of eight different device types (voltage and current class) in TO 247-3 package from Infineon Technologies AG were used.

Power Converters

25 kW High Power Resonant Inverter Operating at 2.5 MHz based on SiC SMD Phase-Leg Modules
Fabian Denk, Karsten Haehre, Christoph Simon, Santiago Eizaguirre, Michael Heidinger, Rainer Kling, Wolfgang Heering, Karlsruhe Institute of Technology (KIT), D

Nominated for the Best Paper Award
Nominated for the Young Engineer Award
In this work we present investigations on a high power resonant inverter operating at 2.5 MHz with ISOPLUS SMPD SiC-MOSFET phase-leg modules. These modules combine excellent thermal performance with very low parasitic inductances and good high frequency switching performance. A prototype of the full-bridge inverter with the SMPD module was built. With this prototype an efficiency of 95% was measured at a switching frequency of 2.5 MHz and an output power of maximal 25 kW could be delivered to the load resistor.

A Trans-Linked 5-kW Inverter Using SiC MOSFETs to Achieve Fan-less Operation
Tatsuya Miyazaki, Hirotaka Otake, Yusuke Nakakohara, Ken Nakahara, ROHM, J; Mamoru Tsuruya, Power Assist Technology, J
A trans-linked interleaved inverter using SiC metal-oxide-semiconductor field-effect transistors (MOSFETs) achieves a power conversion efficiency of 99% at 5 kW. The trans-linked topology leads to a less required inductance of the smoothing reactor formed by the leakage magnetic flux, and the high-frequency switching of SiC MOSFETs also contributes to reduce the inductance more. Thereby less winding turns is applicable in the reactor, and the consequent copper loss of the rector sufficiently trims the total power loss.

High power Constant Current Class EF2 GaN Power Amplifier for AirFuel Magnetic Resonance Wire-Less Power Transfer Systems
Tiefeng Shi, Paul Wiener, GaN Systems, USA
This paper presents the constant current Class EF2 power amplifier (PA) for magnetic resonance WPT with GaN devices, where the current output of the Class EF2 PA remains almost constant when the load impedance varies. The solution enables power transfer coil load of the WPT system to simultaneously support multiple devices and naturally supply the power demanded by receiver with open loop. The Class EF2 PA can deliver 200W CW power at 6.78MHz, with 90% efficiency at 60V.

System Efficiency and Power Density Comparison of Voltage-Source Based DC-Link and Matrix Converters for Highly Integrated Electric Motor Drives
Rüdiger Schwendemann, Marc Hiller, Karlsruher Institute of Technology (KIT), D; Boris Janjic, KSB SE, D
This paper compares power electronic systems (PES) regarding their suitability for system integration in the housing of variable speed drives. The PES are investigated with respect to the required volume and power losses. The analysis of the PES covers a shaft power from 10 to 40 kW and is done with different semiconductor technologies. Based on the investigation results the best combination of topology and power semiconductor type for each power range and switching frequency can be given.

Advanced Sensors

Closed-Loop Hall Sensors with Near Fluxgate Performance for Residual Current Measurement in Photovoltaic Systems
Stéphan Trombert, LEM Switzerland, CH
Closed-loop fluxgate sensors are widely used to measure small residual currents flowing in large and noisy common mode currents. Their accuracy and ability to provide high galvanic isolation make them the "preferred choice" for residual current measurement (RCM), but with the penalty of a costly and physically large design. This paper describes an innovative, reduced foot print, closed-loop sensor for residual current measurement in photovoltaic (PV) systems based on Hall technology.

Evaluation of Overall Accuracy of New Current Sensing Concepts in Comparison to State-of-the-Art Methods
Frank Lautner, Mark M. Bakran, University of Bayreuth, D

This paper investigates the overall accuracy of conventional current sensors and compares it to new low cost solutions. It was found that a typical bandwidth of 30 kHz, which can be reached in open loop Hall effect sensors, leads to errors that exceed datasheet stationary accuracy by far at high motor speeds. Alternative methods, like VCE(on)-based sensing, with higher bandwidth but suffering from poorer stationary accuracy, are found to reach comparable overall accuracy and are hence promising.

Design and Implementation of an Integrated Current Sensor for a Gallium Nitride Half-Bridge
Janes Walter, Javier Acuna, Ingmar Kallfass, University of Stuttgart, D
This work presents the design and implementation of a Printed Circuit Board integrated, inductive current sensor for short-circuit protection of a Gallium Nitride half-bridge. The sensor geometry was optimized numerically for high bandwidth, low additional inductance and low capacitive coupling. The fabricated sensor was measured in the frequency and time domains, showing very good agreement with the simulated results and also in comparison with a reference coaxial shunt.

Utilization of Parasitic Luminescence from Power Semiconductor Devices for Current Sensing
Jonathan Winkler, Jan Homoth, Robert Bosch, D; Ingmar Kallfass, University of Stuttgart, D
In contrast to common current sensing methods where the sensing element must be added, a potential alternative current measurement method based on intrinsic semiconductor properties, namely electroluminescence from power semiconductor devices, is presented.A novel approach for the implementation of a dead time control, as well as a promising conceptual study on luminescence-based current sensing is presented.

Keynote

Electric Vehicles Charging - An Ultrafast Overview
Prof. Dr. Drazen Dujic, Power Electronics Laboratory, EPFL, Lausanne, Schweiz
Electric vehicles charging infrastructure, its costs, availability and performances represent very important factors that will directly impact smoothness of mobility transition and is wider deployment. There are varieties of the electrical vehicles charging technologies, standards, requirements, different technological approaches and different charging levels (both in power and time). The keynote will cover the broad topic of electric vehicles charging and provide an overview of the past and present developments as well as future trends in this field.

New Passive Devices in Power Conversion - Nice to Have or a MUST?
Dr. Petar J. Grbovic, Huawei Technologies, München, Deutschland
Power electronics play significant role in industrial applications, power generation, home appliance, transportation, etc., etc. Until today, significant research effort has been made in the field of power semiconductors and control circuitry. However, somehow minor research effort has been made in the field of passive devices. The Key Note will address the need to invest more in Passive Devices: Magnetic material for medium, high and very high frequencies, capacitors for very high current applications, system integration, passive current sensors and PCB integration.

Modular Multilevel Submodules for Converters, from the State of the Art to Future Trends
Dipl.-Ing. Markus Billmann, Fraunhofer Institute IISB, Erlangen, Deutschland
Modular Multi Level Converters have become a mature and proven technology. This paper describes the need for a next step which should be standardization for the submodules of an MMC converter. A submodule that will combine recent topology improvements with latest available semiconductors is described. As it is difficult to pick one of the actual global players to set one new standard, an option to solve such political challenges is also identified.